ILLUMINATING ENGINEERING

JUNE, 1950

Why 30 Footcandles Minimum for Schoolrooms?
Thermionic Emission in Incandescent Lamps
Committee Report—Lighting for Bakeries
Cold Cathode Operating Characteristics
I.E.S. Lighting Data Sheets
Lighting for Night Driving
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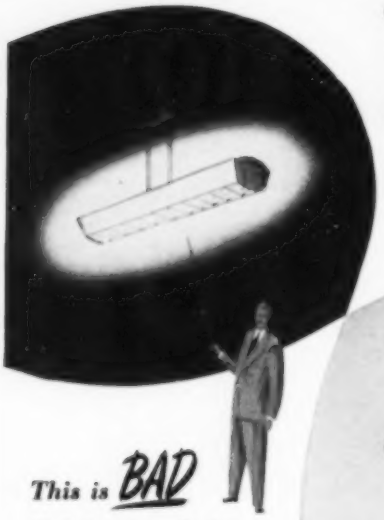
which is the key to the
Co-ordinated Classroom



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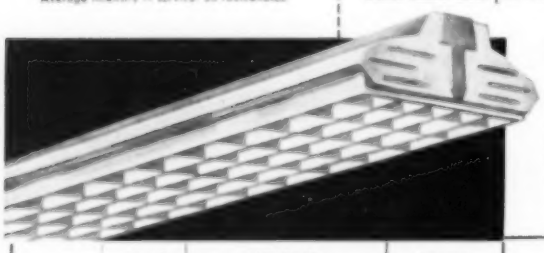

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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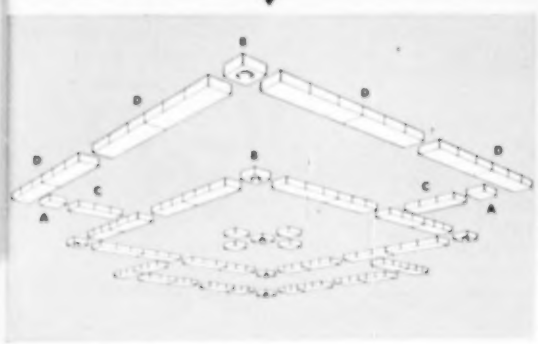

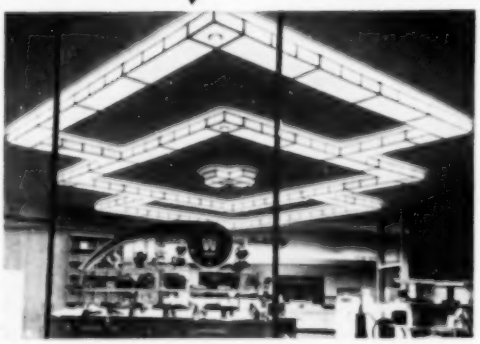

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Starting and Operating Characteristics of Cold Cathode Fluorescent Lamps

By S. M. GRAY

The application of 72-inch T8 cold cathode fluorescent lamps to the lighting of rapid transit cars operated with power from 625-volt direct-current circuits was described in an earlier paper.* In connection with this application, an exhaustive study was made of the starting and operating characteristics of these lamps both in the normal room temperature range, and at low temperatures down to 20°F. In the following paragraphs and charts, a few of the highlights of this investigation are set forth because it is believed that such information should be useful to anyone contemplating the use of this type of lighting equipment.

THE STARTING of a cold cathode lamp in a direct-current circuit occurs in at least two easily recognizable stages.

1. The initiation of a glow discharge.
2. The development of the glow discharge into a stable arc.

The transition from a glow discharge to an arc occurs almost instantaneously under favorable conditions. When voltage and temperature conditions are such as to make the starting of the lamp difficult the development of the arc may require a period ranging from a few seconds to 15 minutes or more. The better the facilities for conservation of the heat generated in the lamp and the smaller the thermal mass to be heated, the shorter is the period of transition from glow to arc discharge. On the other hand, under extremely unfavorable conditions the discharge may never develop into a stable arc.

The volt-ampere curves of 72-inch T8 lamps in Fig. 1 illustrate the change of characteristic which accompanies a rise of lamp bulb temperature. The principal electrical effect of increase of bulb temperature is the reduction of the voltage peak intervening between the glow and the arc phases of the characteristic curve. It is indicated by the curves and corroborated by experience that the discharge cannot develop into an arc unless the ballast load line drawn through a point on the voltage axis corresponding to the supply voltage intersects the lamp characteristic curve at a point beyond the voltage peak.

A discharge in the lamp is usually initiated by a transient voltage supplied by a starter, one form of which is illustrated in the schematic circuit diagram of Fig. 2. When the line switch closes, the flow of charging current into the condenser induces a transient voltage in the secondary coil of the transformer which starts the lamp. For the purpose of measuring the starting requirements of lamps in the laboratory, use was made of a simpler starting device consisting of a condenser which could be charged to a measured potential, then disconnected from the auxiliary charging circuit and rapidly connected across the lamp, the latter being continuously connected in series with a suitable ballast resistor in a circuit supplied by a d-c generator. The peak voltage of the starting transient could thus be varied by control of the condenser charging voltage and the duration of the transient could be varied by exchanging the condenser for one of larger or smaller capacitance.

Three variations of this experimental circuit were used:

(a) Condenser polarity matched to lamp polarity and a hot-cathode mercury rectifier interposed between ballast resistor and generator to prevent the dissipation of the transient energy in the ballast resistor and the generator.
(b) Condenser polarity matched to lamp polarity with no rectifier in the circuit.
(c) Condenser polarity opposed to lamp polarity.

Starting requirements of 72-inch T8 cold cathode fluorescent lamps in a 625-volt d-c circuit at room temperature as determined by use of these experimental starting circuits are recorded in Fig. 3. These results may be described briefly as follows:

1. As the duration of the starting transient is increased the minimum condenser voltage required to start the lamp decreases at first along a constant-energy line and then gradually levels out along a constant voltage line.

2. The insertion of a rectifier in the supply circuit to prevent the dissipation of the transient energy in the ballast

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: Sylvania Electric Products Inc., Salem, Mass.

*"Fluorescent Lamps for High Voltage Direct-Current Operation," by C. I. Brady, Jr., R. G. Slauer and R. R. Wylie, ILLUMINATING ENGINEERING, Vol. XLIII, p. 50 (January, 1948).

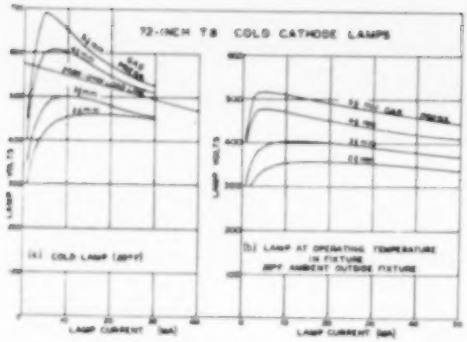

72-INCH T8 COLD CATHODE LAMPS
LAMP VOLTS
LAMP CURRENT (MA)
(a) COLD LAMP (80°F)
(b) LAMP AT OPERATING TEMPERATURE IN FIXTURE (80°F AMBIENT OUTSIDE FIXTURE)

Figure 1.

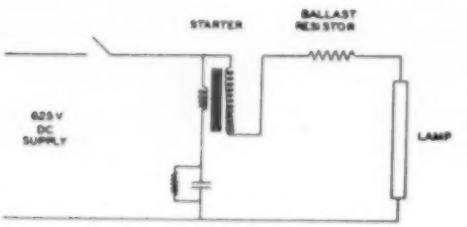


Figure 2.

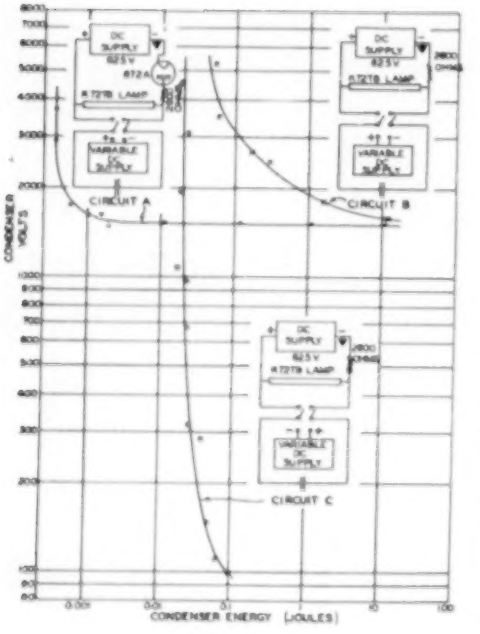


Figure 3.

resistor and the d-c generator reduces the minimum condenser energy required to start the lamp by a large factor. The minimum condenser voltage required to start the lamp is not altered significantly by the insertion of the rectifier. 3. The reversal of the polarity of the condenser with respect to that of the lamp reduces the minimum condenser voltage required to start the lamp by a large factor. The minimum condenser energy required with opposite polarities is, however, approximately the same as that found for the condition of matched polarities with no rectifier.

The most remarkable feature of these results is the relatively low transient voltages required to start a lamp when the lamp and condenser have opposite polarities. Examination of these transients with a cathode-ray oscilloscope has shown that they consist of an abrupt reversal of the lamp voltage, followed by a gradual decrease of the reversed lamp voltage to zero and a gradual rise in the direction of the original polarity. The rising phase of the transient appears to follow an exponential curve consistent with the mathematical analysis of the circuit. Why a transient which reverses the polarity of the lamp should require less voltage to start the lamp than a unidirectional transient is not clearly understood. However, this phenomenon is believed to be the reason for the unusual effectiveness of the type of starter illustrated in Fig. 2 which customarily starts the lamp with a single transient, by way of contrast with the more common glow-switch starter which ordinarily executes a multiplicity of unidirectional transients in starting a lamp. Further investigation of these starting transients is in progress. Assuming a starting transient of adequate voltage and energy, there is yet another requirement for starting of the lamp, an adequate supply voltage. The significance of this requirement is readily appreciated by reference to the relation between the ballast load line and the volt-ampere characteristic of the lamp in Fig. 1(a). The minimum supply voltage that will insure the development of a stable arc in a lamp following the initiation of a glow discharge varies with the gas pressure in the lamp and with the ambient temperature as shown in Fig. 4. At low temperatures the relation between minimum supply voltage and gas pressure is not linear but takes an abrupt step upward between 3 and 5 mm. The reason for this odd behavior at low temperatures is not clearly understood but is probably associated with the almost complete absence of mercury vapor at these temperatures.

Operation

After the lamp is started, a definite period of time is required for the attainment of equilibrium with the ambient temperature. The lower the ambient temperature and the supply voltage the

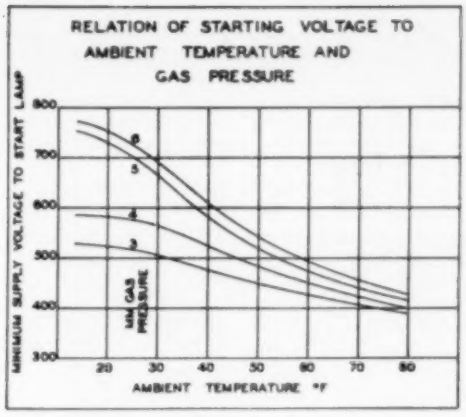


Figure 4.

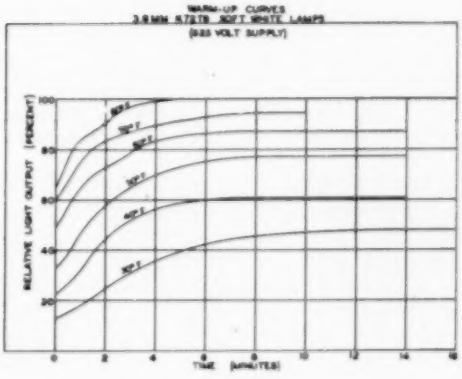


Figure 5.

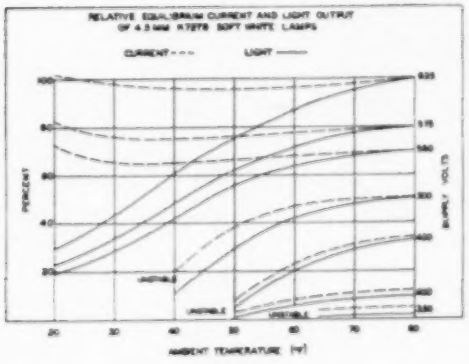


Figure 6.

longer is the stabilizing interval. The relation between warm-up time and ambient temperature for one value of supply voltage is shown by the curves of Fig. 5.

The relative equilibrium characteristics of 72-inch T8 cold cathode lamps over a range of ambient temperatures and supply voltages are shown in Fig. 6.

It is observed that with supply voltages within the normal operating range there is substantially no decrease of lamp current as the temperature declines. In fact, the current tends to increase slightly with declining temperature in the neighborhood of 20 to 30°F. Despite the stability of the lamp current the light output falls off rapidly at temperatures below 50°F, due to attenuation of the mercury vapor pressure within the lamp.

DISCUSSION

F. W. Reuter*: We wish to compliment Mr. Gray for his excellent presentation of the starting and operating characteristics of cold cathode lamps on 625-volt d-c circuits. We were not aware of the easier starting of the lamps if the polarity of the starting condenser were reversed to that of the lamp, and believe this particular point should be of general interest to the fluorescent lamp industry. Otherwise, our data corroborate those he has shown.

Mr. Gray does not recommend any specific filling-gas pressure to be used in 72T-8 lamps for d-c operation. His data indicate some low pressure, 3 mm or lower, is needed for reliable starting of these lamps at low temperatures, particularly with low voltage conditions. It has been pointed out that a low filling gas pressure is a serious handicap to life and voltage and lumen maintenance of these lamps. What, then, is the commercial compromise for pressure?

Were the lamps used for these data new lamps? Some of our tests indicate there is a gradual increase in the starting voltage of d-c lamps with life, particularly, if the operating voltage of the lamp increases due to the gradual lessening in activity of the cathode.

The polarity of lamps operated on d-c must be reversed periodically to prevent the mercury from migrating completely to one end of the lamp. It is our experience the lamps require an appreciably higher starting voltage immediately following this polarity reversal.

We wish to add that 72T-8 lamps with hot cathodes start easier on 625-volt d-c circuits at cold temperatures and with low voltage conditions than do the corresponding 72T-8 cold cathode lamps. Also, starting aids, such as metal stripes and other conducting materials commonly used on or near the bulbs of fluorescent lamps used on a-c circuits, do not help starting on d-c.

E. H. Raddin**: Valuable information has been presented on the performance of 72" cold cathode lamps

*General Electric Co., Nela Park, Cleveland, Ohio.
**Champion Lamp Works, Lynn, Mass.

operated on direct current under favorable and unfavorable voltage and temperature conditions.

The unfavorable conditions for starting the lamps and lumen output are either low line voltage or low temperature and the most unfavorable condition is a combination of both. These conditions are unfavorable to all fluorescent lamps.

Starting appears to be the biggest problem and the data show that the 72-inch lamp with an argon pressure of approximately 4.5 mm, which is commonly used, will not start at 35°F if the line voltage falls below approximately 575 volts.

I am assuming that experience shows that low voltage and low temperature sometimes occur together on electric trains where these lamps are used, and cause the lamps to be inoperative. If this is so, is any change made in the lamp design, such as lowering the argon pressure, to overcome the effect of the combination of unfavorable starting conditions?

I would not think that the loss of lumens at the lower temperature would be very serious because at the time the light is used for passengers it may be assumed that the temperatures in the trains are fairly comfortable and, therefore, favorable to full light output.

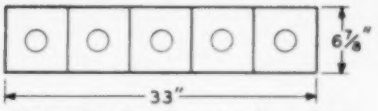
Manlie Jewelry Company—Planned Lighting Winner

Relighting this jewelry store won for Paul Morris, architectural designer of Hammond, Indiana, one of the top awards in the Planned Lighting Competition sponsored by General Electric. Color has been effectively combined with the lighting plan to achieve the winning results. The 13-foot drop ceiling in one section of the 100-foot 9-inch room is a dark blue of approximately 15% reflection factor. In this section, one wall is a light blue, and one a light grey, both of about 50% reflectance. In the other sections, one wall is mirrored to the ceiling, one is light grey; the east walls are light walnut wood panel. In the drop ceiling, two rows of 18 mm 3500K white neon tubing is used in coves, with 60 ma transformers. Twenty-six counter lights with 10° beam offset (without lens) use 150-watt PAR38 incandescent spots. The illumination on the top of the floor cases varies from 110 to 160 ft-c. Direct show case type luminaires highlight the sparkle of the merchandise in wall cases. These employ fluorescent lamps in various sizes, all of 3500K.

Lighting a Glass Window—Wall and Terrace

LIGHTING OBJECTIVE: To provide pleasing general room illumination as a background for informal living with adequate light in some areas for occasional reading and to create a garden "picture" of the terrace.

Installation at Orange, New Jersey



Window-Wall Box Containing Five 60-watt Filament Lamps Above Lenses.

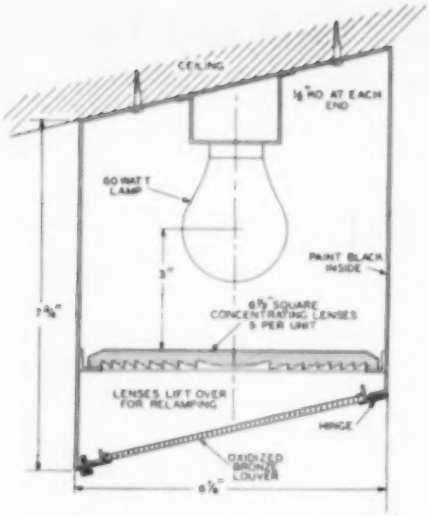
General Information: This room, named by its architectural designers as The Great Room, is a large interior used primarily for informal dining, cards, reading, television, dancing, and music. The house and this room were planned around a huge, spreading beech tree and a terrace. To provide an unobstructed view of the tree and the terrace in its sunny daytime beauty and in its lighted night-time charm, one entire wall of The Great Room is constructed of windows and sliding glass doors. At those times when greater privacy is desired, curtains can be drawn across the upper and lower glass sections.

The room is 19 feet by 25 feet with a pitched beamed ceiling that graduates from 8 feet to 12½ feet in height, with the beams 3 feet apart. The fireplace wall is of earthy-pink stone; the other wall areas are a rose-beige, the ceiling is peach-beige, the curtains and rug are beige, and the floor is reddish brown.

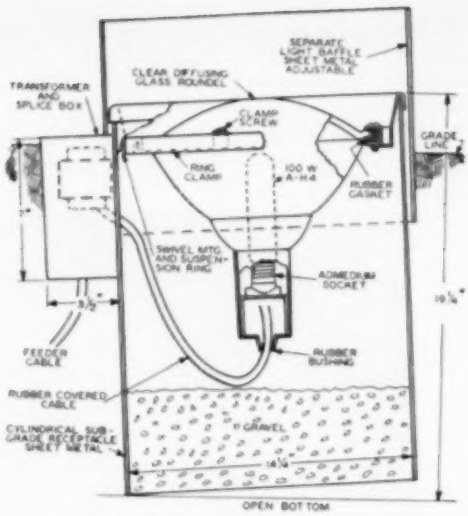
Installation: Two large-scale modern-style 100-200-300-watt table lamps with diffusing bowls provide local lighting for reading at the furniture groupings opposite the terrace wall. To create a balanced lighting effect on the terrace window-wall and to reproduce substantially the daylight "feeling" of luminous curtains, strips of lighting and

(over)

A.I.A. File No. 31/12



Cross Section of Window-wall Lighting.



Outdoor Floodlight Installation.

curtain fabric combine to reflect a pleasant glow into the room. Seven boxes 33 inches long are mounted on the ceiling between the beams and painted the same color as the ceiling. Each box contains five 60-watt inside frosted incandescent filament lamps above 6½" square concentrating lenses. A hinged bronze louver screen is attached beneath each box to reduce lens brightness. The downlights and the window-wall lighting are controlled by a dimmer, allowing flexibility in lighting levels to best serve the varied informal activities in this room. When the outdoor garden scene becomes the center of interest the wall lighting can be reduced by use of the dimmer to a minimal glow.

Footcandle readings on the table top averaged 8; in the immediate vicinity of the window-wall (18 inches from wall on a 30-inch plane) the footcandles averaged approximately 20. The range of brightness readings on the curtains was as follows:

	Top Curtain	*Bottom Curtain*
Shadows in Folds	0.5 Ft-L	0.4 Ft-L
Flat Front Surfaces	5.0 Ft-L	2.5 Ft-L

In the evening with a low level of lighting in the room for dancing or music, light accents the charm and grace of the beech tree. Two 100-watt A-H4 mercury vapor floodlights recessed in the ground as shown in Fig. 4 project light upward through the spreading limbs. Five 150-watt projector spot lamps are installed high in the tree and directed to illuminate the terrace for outdoor living. The terrace is paved with a yellow seashore gravel set in cement. Its high color value and texture provide a soft reflection of light at night.

Equipment: Special louvered lens lighting boxes for the window-wall illumination and the mercury vapor units for lighting the tree are from Kliegl Brothers, 321 West 50th St., New York City. Architect: Emil Schmidlin, East Orange, New Jersey. Architectural Designer: Ellis Leigh, East Orange, New Jersey. Ligating Designer: Richard Kelly, New York City.

Lighting data submitted by Miss Myrtle Fahsbender, Director Residential Lighting, Lamp Division, Westinghouse Electric Corp., Bloomfield, N. J., as one solution of this home lighting problem, and to suggest ideas which may be used in solving similar problems.

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Why 30 Footcandles Minimum for Schoolrooms?

By C. L. CROUCH

A discussion and supporting material for the illumination recommendations in Table II of the American Standard Practice for School Lighting*

THERE ARE several approaches to the problem of determining the illumination for school tasks or any visual task. Most of these are concerned with visual results without regard for visual effort or other demand on the energy resources of the worker. All current approaches can be divided into two main categories: (1) efficacy and (2) efficiency. "Efficacy" has to do with the ability of the eye to see or perform better with increased illumination; "efficiency" is concerned with the energy input to produce the visual output or performance.

Efficacy

1. *Ability of Eyes to See: Characteristics of the Task*

One approach is to analyze the task in terms of its characteristics and to test the ability of the eye to see in terms of the same characteristics, i.e., *size, contrast, time* necessary for seeing and the *brightness* of the task. It has been found that the ability of the eye to see these characteristics increases with the brightness of the task. The brightness of the task depends upon the illumination falling upon it. The darker the material the more illumination is needed to give it brightness.

Increasing the illumination or brightness increases the ability to distinguish fine detail. Increasing the illumination or brightness of the task increases the ability to see smaller degrees of contrast. Increasing the illumination or brightness increases the ability of the eye to see the task more quickly. These effects are shown in Figs. 1, 2, and 3.

Any given task having a particular size, contrast and time factor may be found from such curves to demand only a portion of the illumination being recommended since the curves represent threshold conditions where the eye can just barely detect the detail. To increase the illumination beyond the threshold conditions represents both a safety factor and an easier visual task.

The visual acuity-illumination relationship has long been used as one index of the ability of the eye to see under increasing levels of illumination. Fig. 1 represents an extensive study[1] by R. J. Lythgoe, M.D., D.Sc. under the auspices of the British Medical Research Council. From his curves it is found that with properly illuminated environment, improvement in the ability to see detail continues to increase at levels above 1000 footcandles on test objects. Similar results were obtained from the work of four investigators on contrast whose composite curve[2] is illustrated in Fig. 2.

Work of Ferree and Rand,[3] under the auspices of the National Research Council, showed continuing decreases in time required for seeing at a level of 100 footcandles.

All of these curves showing increasing ability, even though at a diminishing rate, up to hundreds of footcandles, bring about a condition where the selection of the scale of values for the tasks at hand must be made on the basis of the economic situation and current usage.

2. *Speed of Performance*

Some investigators like to use a variation in approach to the problem of recommending levels of illumination and would develop the criterion of speed of performing a visual task with increases of illumination. This is laying particular emphasis on one of the variables as described above, *viz.*, the time necessary for seeing. This represents a variable closely allied to economics since it largely determines the cost of production or accomplishment of tasks. Work on the time factor as a theoretical consideration has been done by Cobb,[4] and Ferree and Rand.[3] Study of the function of work performance has been done by Tinker,[5] psychologist, University of Minnesota and by Weston,[6] Industrial Health Research Board of the Medical Research Council (London).

Tinker has studied the effect of illumination largely upon the speed in performance of reading

*ILLUMINATING ENGINEERING, Vol. XLIII, p. 793 (September, 1948). MR. CROUCH is Technical Director of the Illuminating Engineering Society.

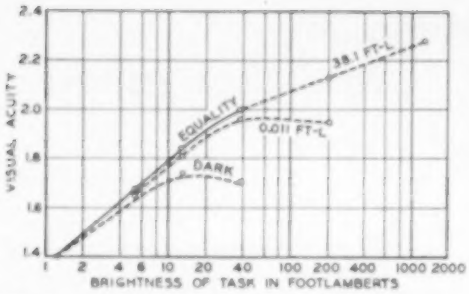

Fig. 1. Increasing visual acuity due to increasing footlamberts brightness of the task. Top curve is with equal brightness of surrounds for the broken line curve. Bottom curves are for low brightness of surrounds or for no brightness as indicated.

tasks. He has found that for 10-point type on good paper there is little to be gained beyond three or four footcandles illumination. For reading newspaper print, 7-point on newspaper stock, there resulted little significant gain beyond seven footcandles. However, he has urged a safety factor to be applied to such tasks and is now recommending 10 to 15 footcandles for good size print (10- to 11-point type) on quality paper and 15 to 20 for the reading of newsprint. For handwriting he recommends 20 to 30 footcandles and for more severe tasks 40 to 50 footcandles.

The British group, under the leadership of Weston[6] at the National Physical Laboratory, have studied over a period of the last fifteen years the effect of size and contrast under controlled conditions of illumination on the performance of a simulated task which might represent reading, writing or any practical two-dimensional task involving size and contrast. They have pointed out that in many tasks there is a certain amount of mechanical action

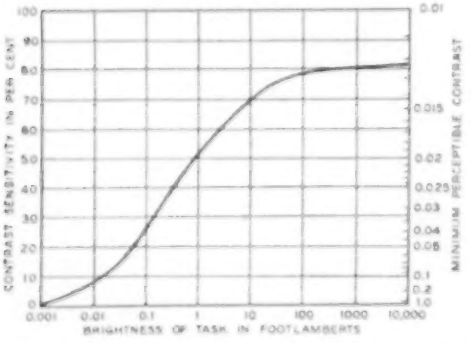

Fig. 2. Increasing contrast sensitivity and improving minimum perceptible contrast due to increasing footlamberts brightness of the task.

time which reduces the apparent effectiveness of the illumination–visual discrimination relationship, and in order to assess the visual performance alone, they subtracted the mechanical action time from the total time of performance. As a result of their extensive work, they have been able to set up formulae covering the illumination required for various percentages of maximum performance in terms of the size and contrast of the task involved.

Comparison of Tinker and Weston Data

Since Tinker has specified the type sizes and quality of paper he used, it is possible to compare

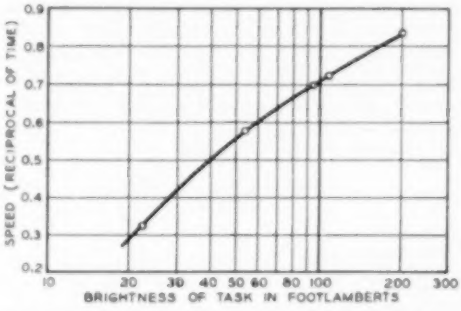

Fig. 3. Increasing speed of reading steel vernier rule due to increasing footlamberts brightness of the task.

roughly his results with those of the British investigators.

There are several points of favorable comparison and in general the divergence is not great when the differences of technique are taken into account.

Discussion of School Tasks

Table I brings into consideration the type of school tasks for which illumination should be specified. There are a variety of tasks performed by the pupils in the typical classroom. However, it is thought by engineers that the lighting should be designed for the most difficult task commonly found in the classroom. Reading is generally from books printed in fairly large type on good paper. Among the more difficult tasks such as reading wall maps, drawing and art work, pencil handwriting is thought to represent as difficult a task for both pupils and teacher as is to be found in the everyday classroom routine.

The similarity of Tinker's recommendations, the Weston data, and recommendations in the "American Standard Practice for School Lighting" for reading pencil handwriting is noteworthy: 20-30, 27, and 30 footcandles respectively.

TABLE I.

Task	Tinker		Weston	
	Bare Performance	Recommended	90% of Max. Performance	98% of Max. Performance
10-point type on 80 per cent reflectance paper	3-4 ft-c	10-15 ft-c	2.5 ft-c	6.5 ft-c
7-point type, newsprint 65 per cent reflectance paper	7	15-20	10.0	24.0
Handwriting — No. 2 pencil on 70 per cent reflectance paper	.....	20-30	12.0	27.0

3. *Relative Visibility or Difficulty*

Another approach involves the use of the Luckiesh-Moss Visibility Meter.[7] It is reasoned that the degree to which the brightness, or the contrast, or the time of viewing must be reduced to cause a task to reach threshold is a relative measure of how visible it is (*i.e.*, how far it is above the "barely seeing" condition). The Luckiesh-Moss Visibility Meter was designed primarily to reduce contrast by rotating an increasingly dense filter. This instrument provides a means to rate various tasks as to their relative relationship (in relative visibility or proportionate difficulty of seeing) to each other or to an assumed reference task. Such relationships are shown in Table III. If a value of illumination is assigned to the reference task, which in this case is 8-point Bodoni type on white paper, other tasks can be rated proportionately according to Table III. For instance, if a recommended value of 10-15 footcandles is acceptable for the reference task, pencil writing would require

$$\frac{200}{100} \times (10\text{-}15) = 20\text{-}30 \text{ footcandles illumination.}$$

It is seen that this method depends on setting a reasonable base illumination upon the reference task.

Efficiency

1. *Index of Energy Input*

Some have reasoned that Nature's levels of from several hundred to several thousand footcandles must have greater significance than mere visual efficacy or performance, the maximum of which seems to occur at lower levels and that there may be benefits in the way of decreased fatigue, decreased energy necessary to accomplish the tasks or the conservation of vision. Attempts have been made to study various physiological reactions under different conditions of illumination in an effort to set up a reliable index of the energy used in the visual performance of tasks. Such measurements are difficult to make and the correlation is complex. Some work has shown a significant relationship and others not. Research is continuing sponsored by the U. S. Navy, I.E.S. Research Fund, and privately. These people are concerned not only with visual *results* or efficacy, but also with expenditure of the worker's *resources* and therefore with his efficiency.

Lighting Specialists' Interpretation

The various approaches are of interest because they all can be utilized in recommending the footcandles for the tasks and through intercomparison allow a weighted judgment.

1. *Characteristics of the Task Approach*

A study of the curves representing the ability of the eye to see individual characteristics of the task in terms of size, contrast, brightness and time, indicate that increases in visual ability are occurring, though at a diminished rate, at levels in the laboratory which are consonant with those found in Nature. The roughly logarithmic response of the eye allows, at much lower levels, a realization of the

TABLE II.—Lighting Levels at the Work.
(Maintained in Service)

Current Recommended Practice for Schools*	
Locations	Minimum Footcandles
Classrooms—on desks and chalkboards**	30
Study halls, lecture rooms, art rooms, offices, libraries, shops and laboratories	30
Classrooms for partially seeing pupils and those requiring lip reading—on desks and chalkboards**	50
Drafting rooms, typing rooms, and sewing rooms	50
Reception rooms, gymnasiums and swimming rooms	20
Auditoriums (not for study), cafeterias, locker rooms, washrooms, corridors containing lockers, stairways	10
Open corridors and store rooms	5

*"American Standard Practice for School Lighting."
**Where schools use chalkboards extensively for demonstration purposes, higher levels than those indicated are desirable.

TABLE III.—Relative Illumination Needed for Tasks of Varying Difficulty.*

Tasks	Relative Footcandles per cent
8-point Bodoni type (used as reference)	100
12-point Bodoni type	50
Good writing on chalkboard (6 feet from board)	100
6-point Bodoni type	170
Own handwriting in pencil	200
Newspaper text (average)	300
Bookkeeping	350
Drafting	400
Shorthand notes	600
Good writing on chalkboard (22 feet from board)	700
White thread on white crepe cloth	1000
Steel scale, 1/64 inch divisions	1800
Black thread on dark cloth	4250

*"American Standard Practice for School Lighting."

Fig. 4. Laboratory set-up for measuring nervous reaction to illumination levels.

effectiveness of a large part of Nature's seemingly generous provision. This may not be strictly true if further work on the index of energy input or the physiological cost of seeing should demonstrate that at higher levels of illumination the small gain of 1 or 2 per cent in visual acuity, contrast sensitivity, or speed of seeing would result in a marked reduction in energy consumed or in the conservation of vision. Until this is further developed, the illuminating engineers and the representatives of the public, through the American Standards Association, must determine the degree of better visibility they desire in terms of visual acuity, contrast sensitivity and speed of seeing which are in keeping with the economic conditions and current usage.

A recent survey[8] conducted by a graduate student of Boston University through a questionnaire to "those responsible for the directing and supervising school lighting in each of 48 states and the District of Columbia" showed that from 20 states reporting on their recommendations of illumination the average maximum value was 26.1 footcandles.*

The National Council of Schoolhouse Construction[9] states

> Some research results indicate that there are visual tasks which require 100 footcandles and above, for optimum visual efficiency. However, for tasks common to schoolrooms, intensities of from 20 to 40 footcandles are practical and available today and are considered to satisfy visual requirements in a balanced-brightness environment.

* Average lowest value permissible, 14.4 footcandles.

Two Canadian reports [10,11] state 30 footcandles recommended and 30 footcandles minimum recommended respectively.

Results of a postwar questionnaire sent to administrators, school board officials and architects by H. W. Schmidt, Supervisor of School Building Service, Wisconsin State Department of Public Instruction[12] show a median value of 30 footcandles within a range of 20 to 50 footcandles.

2. *Speed of Performance Approach*

This represents a conservative approach based upon actual performance of visual tasks involving varying size and contrast. Values from two sources using this approach for handwriting show values of 20-30 footcandles versus 27 footcandles, both of which compare favorably with the 30 footcandles recommended in the "American Standard for School Lighting."

3. *Relative Visibility or Difficulty*

The Luckiesh-Moss Visibility Meter presents the engineer with a mechanical medium which can be used to set up a relative relationship of any unknown task to a reference task. It aids the lighting practitioner to evaluate quickly this relationship and to make relative illumination recommendations according to the difficulty of the task. The final value depends upon the assignment of a basic illumination to the reference task to which all other tasks are related. One value that the designers of the instrument have used frequently is 10 footcandles on 8-point Bodoni type on white paper, representing in their opinion a conservative value for a task equivalent to reading the *Readers Digest*. Another comparative value might be that of Tinker calling for 10-15 footcandles on 10-point type. Thus if a value of 10 to 15 footcandles were assumed for the 8-point reference task, the pencil writing of the classroom would require 20-30 footcandles—a value in close agreement with those described above.

4. *Index of Energy Input*

It is hoped by engineers, physiologists and psychologists that further research, some of which is now underway, will augment the significant work already done in this field and in particular may develop an acceptable index of the physiological cost of performing a visual task. It is the feeling of many that there must be some greater benefits from illumination levels which are higher than those under which one can get the bare maximum performance by pushing young normal or normally corrected observers to their utmost in control cubicles. It would seem that Nature's levels must represent some greater significance to her children's

visual function than performance figures would indicate. Support of such a program is earnestly solicited from everyone who has an interest in vision.

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Louver Panels a Feature of Park Ridge, Illinois School Relighting Program

In their school relighting program, started several years ago, the Board of Education of Park Ridge, Illinois, made extensive use of louverall ceilings with slimline lamps. It was one of the earliest uses of this type of installation for classroom lighting, with the equipment in those days being mostly "tailor-made." In expanding this early trial to the relighting of further old classrooms, they wanted to follow the same general plan. For this purpose a simplified form was selected which was easily adapted to the various plans and ceiling conditions found in old school buildings. The louverall panel installation in the Sewing and Domestic Science Room of Lincoln School, Park Ridge, follows the same louverall theme with modular simplicity, using slimline lamps in standard self-contained units. The lighting is by three continuous rows of five 48" x 96" paneled fixtures, using six slimline lamps per fixture at 200 ma. Illumination level is 120 ft-c at turn-on, and designed to maintain 65 ft-c. The general appearance is reported as very pleasing, with low brightness. The table tops are of a polished black heat-resisting composition, but with this condition the reflected glare is reported as not bothersome. Lighting data and information furnished by David H. Mason, Chicago, Illinois.

Lighting for the Piano in the Home

By E. W. COMMERY
MARY E. WEBBER

RECOMMENDATIONS for lighting at pianos in homes should and can be based on measurement and observation in common with all specific visual problems. Measurement aids materially in resolving problems of lighting and luminaire choice. In the case of the subject of this paper, these problems include the lighting of the piano score, the keyboard, and the pianist's visual field as well as the most advantageous placement of suitable luminaires. These first studies thus propose:

1. To ascertain illumination requirements for the piano score, and thus to supply the basis for including footcandle recommendations for pianos in the Society's Table of Recommended Illumination Values,[1]

2. To establish and locate a rational test plane area and to recommend limits of illumination variation on it,

3. To appraise existing luminaires most frequently recommended or used for this application in terms of objectives 1 and 2, and

4. To suggest ideas for design development which, based on these studies, promise improved lighting conditions for the pianist.

1. *Illumination Requirements for the Piano Score.* — In this investigation reading a piano score is considered on a comparable basis to reading books or papers. Thus, the visibility level of various grades or classifications of typical piano scores were obtained with the Luckiesh-Moss Visibility Meter.[2] Visibility readings were taken at eighteen inches, considered normal viewing distance.

It is recognized that these readings may not actually measure or give full cognizance to the more complex relationships in music reading between reading the score and translating the notes into the hand and foot activity and into the final performance of the player. They do, however, serve as a rational basis for the recommended footcandle levels given in Table I. These values provide about the same visibility levels for reading the piano score itself as is now provided for reading (at a fourteen-inch distance) several sizes of book print (ranging from 6-pt. to 12-pt. type) under the illumination recommended in the Society's Recommended Practice.[1]

2. *Test Plane Area, Its Location, and Test Procedure, etc.* — A high percentage of sheet music and music books measure when open 12 inches high by 18 inches wide; some are smaller, few larger. This 12-inch by 18-inch area represents the actual visual task on which five illumination readings were obtained at the indicated (lettered) positions, Fig. 1, and averaged for each luminaire tested. It is the opinion of the authors that the minimum and maximum readings should not differ by more than 4 to 1. Because the eye when focusing on either page sees an area to the left and right of it, the test plane is extended (beyond the actual music score) 9 inches at either side as seen in Fig. 1. Additional footcandle measurements should be made at these two ends to make sure reasonable brightness-ratios are attained (preferably not exceeding 5 to 1) between the left and right page of the score and their immediate surroundings.

The placement of the lower edge of the test plane above the floor and the tilt of the music plane, Fig. 1, are arbitrarily selected, since different makes and types of pianos vary in these respects. The selected height and tilt of the music plane are common and also represent an average of the extremes found. Comparative tests using a floor lamp revealed small differences in illumination between the lowest and highest music desk locations and rack tilt extremes (not including the miniature spinets). The depth of the music rack base and its distance behind the front edge of the keys vary, and there-

TABLE I.—Recommended Footcandles for Piano Scores

Grade of Piano Music (classification)	Recommended Illumination Level (minimum)
I. Elementary[a]	10
II. Intermediate[b]	20
III. Advanced[c]	40

[a] Representative of the simplest scores for beginners.
[b] Representative of average scores in which sharp, flat, and natural notations appear beside the individual musical notes.
[c] Representative of more advanced scores and handwritten manuscripts in which grace notes and mordent fingering notations occur in addition to complex chord groups. The visibility of advanced scores vary over a wide range. Where notations are printed on the lines (infrequent in good publishing practice) and the entire score is substandard in size, 100 footcandles and more are needed for equivalent visibility levels to those attained above.

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Authors: General Electric Company, Nela Park, Cleveland, Ohio.

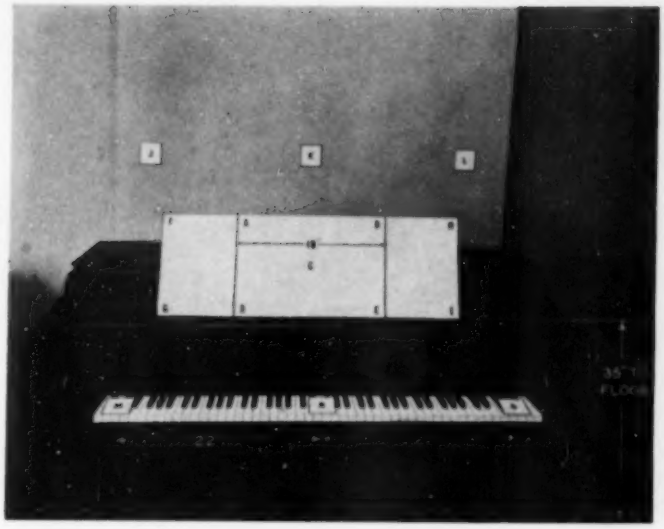

Figure 1. The letters indicate the points of illumination measurement on the test plane, which is 12-inch x 36-inch and tilted 17° back from the vertical, and on the wall and keyboard, explained in Section 2.

fore all luminaire placement dimensions are given in relation to bottom (or in some cases top) edge of the test plane (or music score) as well as to the keyboard center.

It was found that the illumination results from specific luminaires is substantially the same on grand or spinet pianos when the luminaire is identically placed with relation to test plane and keyboard. Because of the nearly vertical position of the test plane, the light reflected from the wall behind it has no effect on the test plane illumination. It does, however, aid in providing a pleasing brightness pattern above and to the sides of the music thereby adding to the visual comfort of the piano player. For these reasons, the tests reported, unless otherwise specified, were made with the plane placed as in Fig. 1 on a spinet piano, centered and placed flat against a wall. Upright pianos were not included in the tests because their manufacture is practically discontinued.

The finish of pianos does not affect materially the illumination at any of the points of measurement. Obviously, however, blond finishes contribute much more favorably to the overall visual pattern than do dark ebony, walnut, or mahogany finishes.

Wall brightness should desirably be within a 5 to 1 ratio of the score brightness. To ascertain whether this is possible with varying wall reflectances, footcandle measurements are given at three points, 6 inches above the top of the plane -- at a center point and 22 inches to left and right. In the few tests made for grand pianos, the test plane was moved out 6 feet from the wall.

The size of the keys and the high contrast between the black and white keys result in a high visibility of the keyboard. From this viewpoint alone, footcandles in the order of 2 to 5 are satisfactory. From the viewpoint of visual comfort, however, keyboard brightness should be within a one to one-fifth that of the test plane.

Specular reflection does not offer serious problems due both to the non-glossy papers used in most scores and to the nearly vertical angle of the music rack. Floor lamps placed at the player's side and in front of the keyboard and lineal sources attached at the top of the rack create small areas of specular reflection, which are increased with increase of the rack tilt.

The tests were conducted in a twelve-foot square room closely approximating the standard test room[3] used for evaluating other residential lighting equipment. All measurements were made with the Luckiesh-Taylor Brightness Meter on a nearly perfectly diffusing white glass plate or on a magnesium oxide disc having 77 per cent and 99 per cent reflectance, respectively. The data were converted to footcandles. All lamp bulbs and tubes used were seasoned, measured for light output, and operated under controlled voltage conditions.

3. *Lighting Performance of Typical Luminaires—Conventional Floor and Table Lamps.* — The angle and position of the test plane present complex problems in obtaining satisfactory illumination

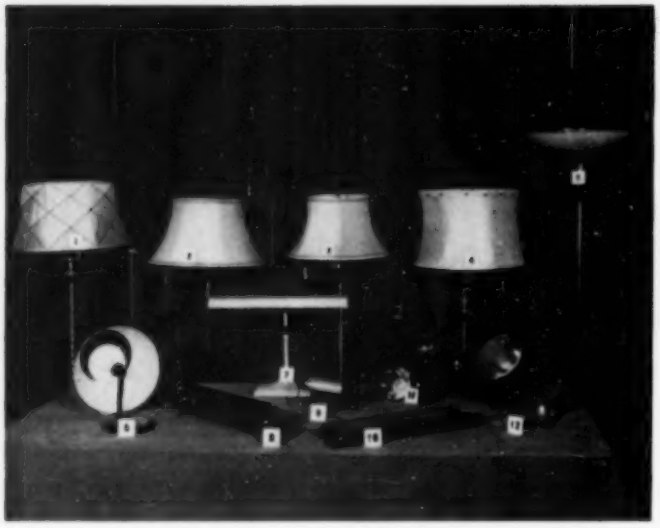

Figure 2. The luminaires studied and tested in this investigation. In the text and in Table III, they are referred to by the numbers given them here.

from conventional floor and table lamps. Inherently, there is very marked decrease in illumination from one side of the piano to the other when only one lamp is used. The need of a pair of lamps is clearly indicated. It is unfortunate that the use of two lamps of characteristic scale is seldom decoratively acceptable. The general-purpose floor lamp models (No. 1, Fig. 2) naturally produce the most, though still low amounts of direct light on the plane. They must be placed in front of the keys about in line with the player's shoulder to obtain substantially more than 20 footcandles (see Tests 1 and 7, Table III). This placement is awkward, inconvenient, and unattractive, except possibly at grand pianos or at corner-placed spinets.

The swivel-arm models have the important advantage of more suitable placement of the base at either side of the piano. The arm can readily be pulled forward and well ahead of the music score. Its lower height means that most of the plane illumination is by transmission through the shade and by reflection from ceiling and wall. (Opaque shades thus should not be considered.) The light distribution is still not all to be desired, even though more light per watt is obtainable from this lamp type (No. 2-4, Fig. 2).

With totally indirect torchieres (8-foot 6-inch ceiling) about 9500 lumens (two 300-watt lamps) are required for 15 footcandles on the plane.

Due to the limitations of placing conventional table lamps on both grand and spinet pianos, the light source is of necessity either in line with or behind the center of the test plane. It is therefore impossible to obtain satisfactory illumination from them except with undesirably large or bright shades.

Rack-Attached Luminaires

It is natural that "local" lighting units of tubular shape have been developed to be attached directly to the music rack. Several representative models for both spinet and grand pianos were included in these studies (Fig. 2). None of them are in harmony with the beauty of the piano nor offer any over-all lighting improvement over conven-

TABLE II.—The Effect of Tube Placement on Test Plane Illumination

(Data were obtained using a 15-watt T-8 fluorescent tube in horizontal position parallel with the test plane. Lamp is shielded from viewer by black-lined narrow reflector.)

Distance Out From Top of Plane*	Average Footcandles on 12" x 9" Plane	Ratio of Maximum to Minimum Footcandles
**1½ in.	30	12:1
2½ "	45	13+:1
3½ "	55	11+:1
4½ "	58	9:1
5½ "	55	7:1
6½ "	45	5:1
7½ "	44	3+:1
8½ "	37	3:1
***8½ "	50	3+:1

*Tube axis is 2½ inches above top of plane, which is tilted back 17°.

**Footcandles on keyboard at M. N. O. are 3, 10, 3, respectively.

***A white paper lining is added to reflector. Footcandles on keyboard at M. N. and O. are 7, 28, and 7, respectively. The tube may be raised two inches without significant change in effect.

TABLE III.—Lighting Performance Data

For brevity X is used to represent position of keyboard center and Y for position of lower edge of test piano (or music rack).

Luminaire Description and Placement	Av. Ft-c from Piano Positions A, B, C, D, E* (min.-max. Variation)	Brightness Ratio		Ft-c on Wall J, K, L*	Ft-c on Keyboard M, N, O*	Comments
		AD to FG*	BB to MI*			
Test #1 CLM (A bowl), luminous shade, #1, Fig. 2, 100/300w. plus 33 w. circline. Lamp axis 34" left of X and 3" in front of Y.	14 (10-25)	1:4	1+:1	29, 15, 9	115, 35, 14	*Satisfactory for elementary scores*, although high keyboard brightness at one end distracting. This lamp type without circline provides 10 footcandles: a balanced pair, 20 footcandles. The use of an opaque shade or a placement which puts the lamp axis in line with or behind Y proved unsatisfactory.
Test #2 CLM (B bowl), 12" swing-arm, luminous 16" shade, #3, Fig. 2, 50/150w. Lamp axis 22" left of X and 10" in front of Y.	14 (5-41)	1:6+	1+:1	9, 6, 4	72, 28, 6	*Too great variation* in 12x18" plane illumination — and on keyboard. Model with circline and 18" shade, #4, Fig. 2, produces 20 ft-c with better distribution but not within 4 to 1. A pair of either type more satisfactory and in better scale with spinets than #1.
Test #3 Pair of torchieres—66" tall, 16" shallow, white-inside dense glass bowls, #5, Fig 2, 100/300w. ea. Lamp axis 34" to left and right of X and in line with Y.	15 (14-16)	1+:1	1+:1	17, 19, 17	20, 22, 20	*Very smooth distribution* for elementary music. Lower torchieres satisfactory if bowls have efficient reflecting surface. Equally satisfactory at grand piano as placed in test room.
Test #4 Ceiling-attached-swivel-socket spotlight #12, Fig. 2, 75w. R-30 flood type. Socket tilted 55° below horizontal, 24" in front of Y center and 8'2" above floor.	17 (13-20)	2:1	2:1	13, 20, 13	12, 18, 12	*Very satisfactory*. The R-30 spot lamp gives over 40 footcandles on plane but less light in surrounds. If ceiling position allows socket of the R-30 flood at 7'6" above floor, over 20 footcandles are supplied. The bulb can be in vertical position —but gives less light and must be no more than 20" in front of Y.
Test #5 Swing-arm — 15" extension arm, 10" bowl, 18" luminous shade, #2, Fig. 2, 100/300w. Lamp axis 22" left of X and 13" in front of Y. Tested at grand piano — keyboard 6' out from wall.	20 (13-38)	1:3+	1+:1	8, 10, 8	103, 43, 14	*Satisfactory for intermediate scores* —except for high brightness distraction one end of keyboard. A more transmitting shade than used in test (av. 100 ft-L) would slightly increase result, although the size of the shade used here is larger than (usually) supplied on lamps of this type.
Test #6 Wall lamp — 11" bottom dia. #6, Fig. 2, 150w. R-40 white indirect bulb. Tested at spinet turned at right angle to wall. Lamp axis 22" left of X and 11" in front of Y. Mounted 48" from floor to lower edge of shade.	21 (9-42)	1:3+	1+:1	(wall 6' distant) 4, 2, 2	77, 32, 8	*Only fair*. High brightness shade (over 400 ft-L) not seen by player but annoying for other occupants of room. Two lamps of this type above spinet placed flat to wall will supply less than 5 ft-c on test plane.
Test #7 Same as #1. Lamp axis is 20" left of X and 18" in front of Y.	38 (17-83)	1:4	2:1	17, 15, 10	120, 39, 9	*Only fair*. This rather awkward position provides highest ft-c possible from this lamp type. Without circline, 29 ft-c and poorer distribution. Opaque shade worse. If spinet is placed in room corner and lamp on wall side, illumination increases 15%.
Test #8 Tubular reflector, ivory finish, on adjustable table stand for spinet only, #7, Fig. 2, 15w. T-8 F. Tube axis 3½" above top of plane and 4" in front of it—tilted 18° below horizontal.	38 (6-74)	33:1	1:33	3, 12, 3	3, 9, 3	*Very uncomfortable*. Poor distribution across full test plane indicates need of longer tubular source and one extending further from plane. See Fig. 4.
Test #9 Ceiling mounted spotlight with swivel socket, #12, Fig. 2. 150w. R-40 Flood. Socket tilted 55° below horizontal and 24" in front of Y center and 8'2" above floor.	45 (36-53)	1+:1	1+:1	27, 54, 27	30, 45, 30	*Very satisfactory for advanced scores*. A PAR-38 lamp of spot distribution provides over 200 ft-c on 12x18" plane, but is too concentrated and in too high contrast with wall and rest of test plane. About 100 ft-c with PAR-38 Flood and similar distribution to R-40.

TABLE III.—*Continued*

Luminaire Description and Placement	Av. Ft-c from Plane Positions A, B, C, D, E* (min.-max. Variation)	Brightness Ratio AD to FG*	Brightness Ratio BE to HI*	Ft-c on Wall J, K, L*	Ft-c on Keyboard M, N, O*	Comments
Test #10 Base-of-rack unit for grand piano with ribbed clear glass shield. #10, Fig. 2, 15w. T-8F. Tube axis 2½" in front of test plane and 1" above rack.	43 (13-78)	57:1	1:57	less than 1	less than 1	*Very poor light distribution.* Ribbed glass aids distribution, but axis must be 4" in front of music before 4 to 1 distribution attained. Less effective unit, #6, Fig. 2, (also for grand pianos only) sets down on tuning rods in front of rack: very poor distribution unless rack pushed to extreme position, 24" or more from eyes.
Test #11 Pair of experimental table lamps with 12" extension arm. See Fig. 3 and discussion Section 4. 100w. Deluxe white lamp ea. Lamp axis 16" to left of X and 10" in front of Y. Data for grand piano and for shades (140 ft-L) having a 2" vertical section of much higher transmission (450-2000 ft-L).	52 (36-65)	1:2+	1:2+	(wall 6' distant) 4	85, 80, 65	*Very satisfactory* and could be used on some types of spinets. Good styling would seem possible since shades can be in better scale than most conventional floor or table models. With shade of approximately 175 ft-L and no special vertical section, about 35 ft-c. It is questionable that this brightness level would be acceptable so close to eyes.
Test #12 Experimental reflector, 24" long, 5" wide, 3" deep, tilted 20° up from horizontal. Two 20w. T-12F. Center of tube axes 9" in front of test plane top and 3" above it.	125 (78-170)	3+:1	3+:1	9, 25, 9	25, 90, 25	*Very satisfactory.* Refinement of design and good means of attaching to back of piano needed.

*See Fig. 1.

tional portable lamps. They are much more economical of electricity, and in general, they provide a higher average illumination on the 12 inch x 18-inch plane. Only the relatively short incandescent unit (No. 9, Fig. 2) gives less than an average of 20 footcandles, and data for it are not included in Table III. They all create harsh brightness ratios in the visual field. Generous lighting from other room lighting is essential when they are used.

Most important is the fact that the tube is placed so close to the rack that there is a most undesirably sharp drop-off in light with distance from the source. To emphasize the necessity of better spacing between the source and the plane, the data in Table II are presented. A test plane equal to one page of music centered on the rack was used.

A shield of ribbed clear glass over the tube greatly improves the light spread (see Test No. 10). With its use, a 4 to 1 distribution is obtained at one-half the distance indicated in Table II.

Ceiling Spotlights

The smoothest lighting of the pianist's entire scene at illumination levels for all music score classifications was found with the use of incandescent reflector and projector bulbs with flood distribution. These are placed in typical swivel-socket units, such as No. 12 in Fig. 2, which may be ceiling mounted or, in the case of lower ceilings, semi- or totally-recessed. Many types for both mountings are on the market. They present the necessity of permanent piano placement, specific wiring, and definite luminaire placement, but in many cases these are not serious drawbacks especially in view of their excellent results. These same bulb forms, designated at R-30, R-40, and PAR-38, with spot distribution, when identically placed, provide up to five times as much light on the 12-inch x 18-inch plane, but also direct far less light on the remaining test plane and wall with very uncomfortable results.

Placement of the three classes of luminaires considered in this paper is usually critical, and full descriptions and test data are included in Table III.

4. *Suggestions for Further Development.* — It is apparent from a study of the test data that there is need for more design development of *portable* equipments which more completely satisfy both the lighting and aesthetic considerations of piano lighting. In new designs, effort should be directed to obtaining 40 footcandles or more. Presumably everyone who spends any considerable time at the piano is or will be reading advanced music scores! In these initial, though not completely exhaustive studies, three possible developments, one in each of the three luminaire classifications discussed, seem worthy of further design and style attention.

a. A pair of table lamps of an entirely new form, for this application only, offer interesting possibil-

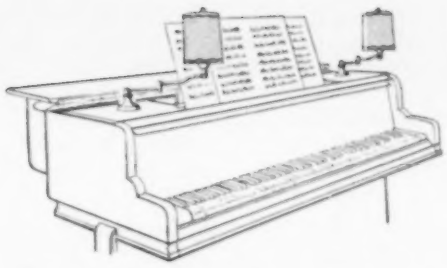

Figure 3. With added design skill, delicately scaled extension table lamps (shown with special shades 5-inch top, 6-inch bottom, and 7 inches high) could be a new solution for excellent lighting at the grand piano as well as some spinets, and also be attractive piano ornaments. See discussion, Section 4a.

ities. (See test No. 11 and Fig. 3.) They would seem to need very short bases incorporating either a swing-arm or pull-out extension (at least 12 inches to position the light well ahead of the score) and dense cylindrical shades, having a 2-inch vertical section of high transmission. When the shades are turned so that the narrow "slot" aims its light (from 100-watt Deluxe white lamps) at the score, the player cannot see its high brightness nor can other occupants of the room if the lamp's over-all height is about that of the score. When not in use, the socket can be pushed back into normal position, the "light" section turned from view, and take on the semblance of purely decorative ornaments. Plastic and various composition papers should lend themselves to the suggested treatment. With ingenious handling, possibly straight-sided silk shades could attain this effect by omitting a section of the lining.

b. While all the rack attachment units are far from attractive, they could be improved both in scale and in effectiveness. Designers might well consider the use of the 13-watt T-5, 21-inch tube for more delicately scaled units and for better coverage of the score and surround. A simple, white-lined shield can have delicate dimensions with the 13-watt lamp, if a manual switch is used and the ballast is mounted on the back of the piano. The shield should be formed to cut the light at the front key edge and to protect eyes of those standing by the player. The unit in its simplest form could be supported with a rod attached on the back side of

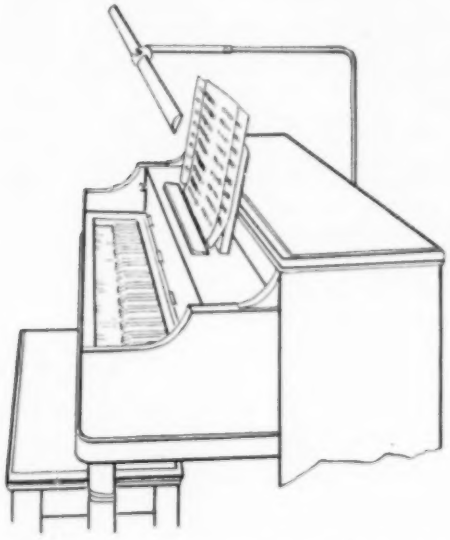

Figure 4. The suggested "local" light offers design challenge to overcome its mechanical appearance. But it shows the small scaling possible for the tube and shield unit and its most desirable positioning for lighting not only of the music score but wall and keyboard. See discussion, Section 4b. Small dimension and appropriate finish may go far in making it inconspicuous.

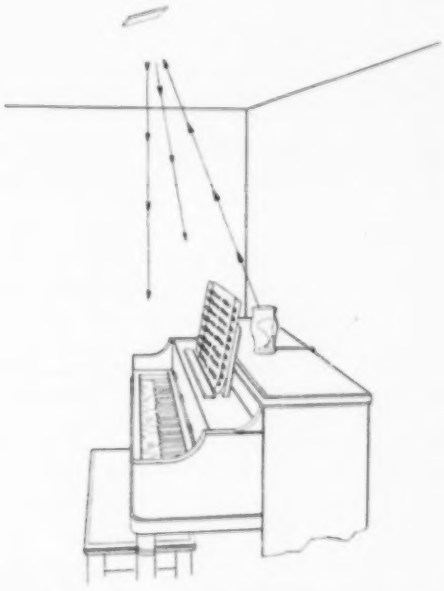

Figure 5. A decorative urn-shaped vase (at least 6" in diameter) can house a projector spot lamp for unusual and dramatic effect. It depends on the use of ceiling mirrors at the correct angle to redirect its light back to the music rack and keys. See discussion, Section 4c.

the piano. It should have adjustability in both vertical and horizontal sections to make it applicable to all sizes of spinet pianos. In correct position, the horizontal axis through the lamp should be about four inches above and eight inches out from the top of the music (an instruction which should accompany the unit), as noted in Table II. See sketch Fig. 4.

Certainly skillful designers can devise more suitable and decorative holders for the tube and shield — table-based or wall-attached. On the market is a most attractive table form, with lyre-shaped standard (ballast in base) and graceful curving arms to support the tube. (It needs some slight rehandling to place the tube as indicated herein.)

e. Although the reflector and projector type bulbs with *spot* distribution proved unsatisfactory when directed from the ceiling to the music rack, they do have a possible application which would not require permanent wiring. One of these lamps may be concealed in a suitable urn-type vase (see No. 11, Fig. 2) placed in back of the music rack. It depends on the use of a mirror (or mirrors) placed at correct angles to reflect its light back to the score and keyboard. With the lamp tilted 15°, the mirror, approximately 10 inches x 24 inches, must be tilted about 30° to light the rack and keys. It would be possible to decrease the size of the mirror by use of several smaller sections, each appropriately tipped. With an 8 ft 6 in ceiling (the bulb placed 44 inches above the floor), about 65 footcandles can be expected. If clear ribbed glass is placed correctly over the bulb, the "spot" is spread lengthwise for softer appearance and about 30 footcandles on the score. Additional room lighting is needed on the wall. In lower-ceiling rooms and on taller spinets (or uprights) the smaller 75-watt reflector spot (R-30 bulb) may be used.

In some new homes, a niche may be planned for spinet piano placement. Then it is quite simple to attain 40 footcandles and more by placing fluorescent tubes above thinly-etched glass in the soffit above. Or in small music rooms it is possible to build sufficient general lighting to augment the illumination and improve the distribution of conventional floor lamps and special piano units.

It is hoped that the data and discussion set forth in this paper may awaken the lighting practitioner and equipment manufacturer alike to greater attention to and study of this long-neglected but visually important lighting application.

The authors wish to acknowledge the assistance of Mr. A. A. Eastman in making the visibility readings of selected music scores.

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DISCUSSION

MYRTLE FAHSBENDER*: How to light the home piano is a query that has been asked of every lighting consultant. Up until now the answers have been based on experience and general accepted practice. The authors of this splendid paper have made a real contribution in setting forth, for the first time, a test plane area, and recommending illumination values for three classifications of piano scores.

From the authors' tests, only three and possibly four types of floor lamp models most commonly used in the home, perform satisfactorily for this seeing task. In my opinion, instead of a floor lamp, most home-makers would prefer a neat, attractive, and inconspicuous device that can be attached to the piano. The few such items that are now on the market were tested by the authors who found that they did not meet the quantity and quality requirements established for satisfactory performance. It is hoped that the authors will interest some manufacturer in developing a portable unit for attachment to the piano that will produce acceptable illumination for all classes of scores.

I would like to suggest that the authors submit piano scores in three classifications suggested in their paper to the Residence Lighting Committee to aid the Committee in their study of the footcandle values the authors have recommended for the reading of sheet music.

*Westinghouse Electric Corp., Lamp. Div., Bloomfield, N. J.

Attention I.E.S. Members

The National Technical Conference is a month earlier this year.

Remember—August 21-24, Huntington Hotel, Pasadena, California

Lighting a Card and Record Shop

LIGHTING OBJECTIVE: To provide general illumination and highlight merchandise in a small store.

Installation at Martha Jane's Melody Lane, 3600 South Carrollton Avenue, New Orleans, Louisiana. Architects: Diboll, Kessels & Associates; lighting designed by Norwood J. Oge, New Orleans Public Service Inc.

General Information: Martha Jane's Melody Lane sells radios, phonograph records and greeting cards in a 100 x 25 x 14 foot area. In the front and along one side are large glass bays covered with drapes which are drawn back at night to show the store's interior.

Surface characteristics are as follows:

side walls	knotty pine	50% RF
ceiling	ivory acoustical board	65% RF
floor	green and white rubber tile	50% RF
furniture	light oak	50% RF
listening booths	knotty pine	25% RF

Installation: Approximately 50 footcandles of general illumination is provided by thirty-two semi-direct, egg-crate louvered, ceiling-mounted, fluorescent luminaires (Pittsburgh Reflector Co. #A-7440) each containing four 40-watt 3500 K lamps; sixteen 150-watt concentric-louvered downlights (Pittsburgh Reflector Co. #A-178-14) equipped with PAR 38 spotlights; and sixteen 300-watt incandescent

(over)

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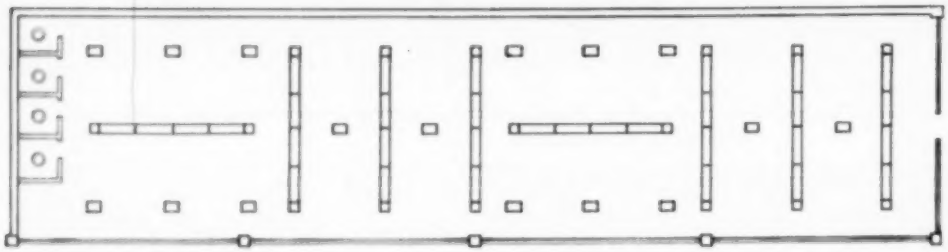

PITTSBURG REFLECTOR CO. NO. A-1440 LUMINAIRE EQUIPPED WITH 4 40W FLUORESCENT LAMPS

HOLOPHANE CO. NO. E-1774 DOWNLIGHT EQUIPPED WITH 1 300W FILAMENT LAMP

PITTSBURG REFLECTOR CO. NO. A-178-14 ADJUSTABLE DOWNLIGHT EQUIPPED WITH 1 150W PAR 38 SPOTLAMP

HOM-O-LITE CORP. NO. 3001 LUMINAIRE CONTAINING 1 32 W CIRCLINE FLUORESCENT LAMP

lamps mounted within light control lens units (Holophane #E-1774). Listening booths are lighted to 20 footeandles by 32-watt 3500 K ceiling-mounted semi-direct circular fluorescent luminaires (Hom-O-Lite #3001). Greeting card racks are highlighted with case-mounted 30-watt 3500 K fluorescent strip.

Brightnesses are indicated below:

lower side wall	11.5 footlamberts
upper side wall	17.5 "
ceiling (between luminaires)	19.5 "
floor (between luminaires)	19.0 "
counter	23.5 "
listening booths (wall)	5.0 "

Lighting data submitted by S. C. Berdon, New Orleans Public Service, Inc., 317 Baronne Street, New Orleans, Louisiana as an illustration of good lighting practice and to aid in the design of similar installations.

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Thermionic Emission in Gas-Filled Incandescent Lamps

By RICHARD H. CLAPP

IN THE MANUFACTURE of argon-filled incandescent lamps, prevention of arcs when the lamp is first lighted-up at rated volts is accomplished by "flashing" the lamp. This flashing consists of prelighting the lamp for a few seconds at some intermediate voltage, usually about 70 per cent of rated value, followed by similar intervals of lighting at successively higher voltages until about 95 per cent of the rated volts of the lamp is reached. By this method the lamp is said to be "cleaned up" and the tendency to arc upon subsequent relighting at rated voltage is reduced almost to zero. There are, however, some lamps which have a higher tendency to arc than others after such a flashing procedure. The determination of the cause of this prompted the work summarized in this paper. Furthermore a lamp will not give consistent readings of watts or lumens per watt until the lamp has been well aged at higher than rated volts for a considerable period of time.

The purpose of this paper is to show correlation between the liberation of impurities from the filament (and the thermionic emission associated with this liberation) and the unstable conditions causing arcs, high watts, and low lumens per watt. For purposes of simplification, all voltages, currents, temperatures, etc. referred to are in respect to lamps containing 100-watt, 120-volt coiled-coil filaments in an argon-nitrogen atmosphere.

Tendencies of Lamps to Arc

The tendency of an unaged lamp to arc when lighted at rated voltage can be varied over an extensive range by using different methods of flashing.

This is shown in Fig. 1, where the results in respect to arcs are indicated for lamps which were flashed under varying conditions of voltage and time. Those flashed under the voltage and time limits of Area *A* had about a 50 per cent chance of arcing when subsequently relighted at 120 volts; those of Area *B* substantially all arced on relighting; those of Area *C* in almost no case arced on relighting; while those of Area *D* tended to arc 100 per cent at the flashing voltage and never reach relighting. Obviously, those near the boundaries of the Areas have intermediate properties.

In order to examine this function of "cleaning up" or "flashing" a lamp, the following points were first noted.

(a) There is insufficient, if any, pressure change in the argon-nitrogen fill to account for any change in the tendency to arc.

(b) There is no measurable change in argon-to-nitrogen ratio which might account for a change in the tendency to arc.

(c) There is no direct correlation between the change in crystal structure of the tungsten metal and the tendency of the lamp to arc, since these changes occur at different temperatures and periods of time.

(d) There might be a clean-up of impurities in the argon-nitrogen fill (as in the case of flashing a vacuum lamp).

(e) There might be a clean-up of impurities in the tungsten metal.

Of these latter two possibilities, the clean-up of impurities from the tungsten metal is shown to be the critical factor. In investigating this, several

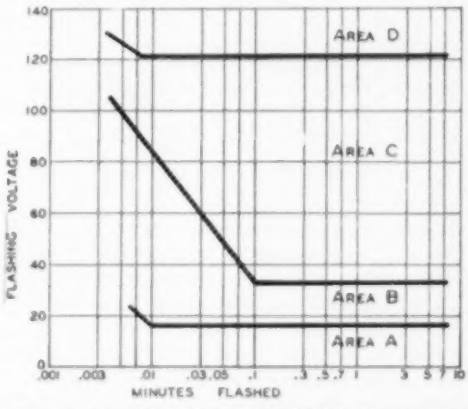

Figure 1. Correlation of flashing schedules (voltage and time) with arcs. Lamps flashed on the schedules represented by: Area *A* might arc on relighting; Area *B* all arced on relighting; Area *C* did not arc on relighting; Area *D* arced during flashing.

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: General Engineering Lamp Division, Sylvania Electric Products Inc., Salem, Mass.

lamps were made up, flashed and relighted at 120 volts in the usual manner without arcs. In a portion of these cleaned-up lamps the old filament was replaced by a new filament in the same argon-nitrogen mixture. This combination (new filament, old gas) caused arcs when relighted at 120 volts. Conversely, in another portion of these cleaned-up lamps the old argon-nitrogen mixture was replaced by a fresh mixture, and with this combination (old filament, new gas) no arcs occurred on relighting at 120 volts. It is therefore evident that the clean-up is a function of the filament and not of the gas fill.

Furthermore, it can be shown that a filament whose surface is contaminated with superficial impurities has a much higher tendency to cause arcs in a lamp than one whose surface is chemically clean. The curves of Fig. 2 are illustrative of this.

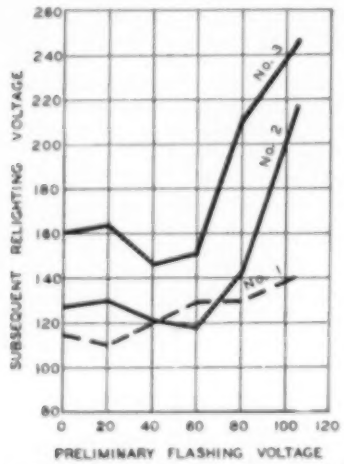

Figure 2. Correlation of cleanliness of filament, flashing voltage (for 3-second flash) and tendency to arc.
Filament Group No. 1 — dirty
Filament Group No. 2 — control
Filament Group No. 3 — specially cleaned

The filaments of Group No. 1 were improperly rinsed after treatment in regular cleaning agent. Those of Group No. 2 received the normal cleaning operations, and were used as controls. Those of Group No. 3 were similar to the controls, but received, in addition, further cleaning by special chemical processing. The flashing voltages used (3 seconds duration in every case) are shown in the abscissa, while the ordinates represent the voltages which the lamps could subsequently withstand without resulting in arcs. This latter is defined as the critical relighting voltage, and is the inverse of the "tendency to arc." These results show the lower arcing tendencies of the progressively cleaner filaments, and the still lower arcing tendencies obtained by flashing the filaments between 80 and 100 volts for a period of 3 seconds. Flashing between 20 and 60 volts increases the tendency to arc (similar to Area *B* of Fig. 1).

Referring still to the curves of Fig. 2, it should be noted that the specially cleaned filaments in Group No. 3 when flashed at 80 volts have no greater tendency to arc than the normally cleaned filaments in Group No. 2 when flashed at 100 volts. Yet the former filaments are superior in mechanical strength to those flashed at 100 volts, since flashing at this resultant higher temperature causes a change in the internal structure of the tungsten and produces a weaker filament. A filament flashed for 3 seconds at only 80 volts is less subject to breakage during transportation and handling, prior to its ultimate burning in service, than is a filament flashed at 100 volts.

Thermionic Emission

It is well known that when a pure tungsten filament is heated to incandescence, electrons are emitted. If a collector plate with a small positive voltage is placed within a few millimeters of the filament and connected through an external circuit to the center tap of the filament transformer, a plate current can be observed and measured. If this is done in an argon-nitrogen atmosphere, this current may be shown to be space charge limited, and does not increase above a certain fixed value with increasing filament temperature.

The emission from a tungsten filament which has been fully aged (such as by operating a 120-volt filament at 130 to 150 volts for several hours) may be considered to be the same as from a pure tungsten filament, and can be shown to have the characteristics described above. This we shall identify as the "normal" thermionic emission of the lamp. This normal emission does not change materially with time. With a "raw" or unaged tungsten filament an additional emission current is found which we shall identify as "excess emission." This excess emission is a function of both filament temperature and time. If, for instance, a raw lamp which has not been previously lighted (and which is equipped with a suitable plate at some plus 45 volts D. C. with respect to the center of the filament) is lighted on a schedule in which the filament voltage is increased in 10-volt steps every five minutes, the total current in the plate circuit may be read and the result plotted. Curve *A* of Fig. 3 is typical of such current readings, which increase

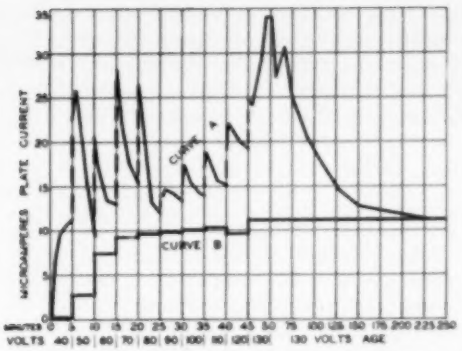

Figure 3. Thermionic emission of lamp before and after aging.

Curve *A* — Total emission from previously unlighted lamp when voltage was increased in 10-volt steps every five minutes and then aged for three hours at 130 volts. Curve *B* — Normal emission from same lamp after aging, when retested under the same voltage-time cycle.

temporarily with each 10-volt increase in filament voltage and then decrease with time as each voltage is held constant. Readings were taken from 40 volts (the lower limit of measurable emission) up to 130 volts in five-minute intervals; the lamp was then aged out at 130 volts for three hours more, at which time equilibrium emission was attained. When this fully-aged lamp was then re-run through the same voltage-time cycle, a curve of the normal emission of the lamp was obtained as shown in Curve *B*. The area between Curve *A* and Curve *B* represents the excess emission given off by the raw lamp.

This excess emission is evidently dependent upon the volatilization of impurities in a thermally-ionized state from the raw filament, and it deteriorates with time as a portion of these impurities are removed from the filament at a given temperature. These ions themselves, however, do not produce the excess emission currents observed. For one reason, their quantity is believed to be too small to have any such effect, and furthermore, no positive-ion emission can be observed as plate current by reversing the polarity of the plate. The effect is rather as follows.

Assume a positive ion to be emitted from the filament by thermal ionization of an impurity molecule along with the large number of normally emitted electrons. This positive ion will be accelerated into the negatively-charged field of the space charge surrounding the filament, and because of its opposite charge will neutralize the effect of an electron comprising the space charge. This in itself would be a minor effect except for the relative velocities of the electron and the positive ion. The true effectiveness of the ion will be proportional to the time spent in the field, which time is inversely proportional to the square root of its mass. Thus the effectiveness of the ion over the electrons is directly proportional to the square root of their masses, or in the ratio of $(1836M)^{\frac{1}{2}}:1$, where M is the molecular weight of the ion. This makes a sodium ion equivalent to some 200 electrons, or a potassium ion to 270 electrons. The effect of the positive ions is to reduce the effective space charge, thus allowing many more electrons to pass through that region and reach the plate from the filament. The excess emission current is thus a current consisting of electrons emitted thermally from the filament and liberated from the space charge by positive ions, these positive ions being produced thermally by volatilization of impurities from the filament.

This excess emission current may be expressed as microampere-minutes of plate current, and two or more filaments may be directly compared as to excess emission in this manner. Nevertheless, it may be shown that this excess emission current is not directly proportional to the rate of loss of impurities from the filament. If two control filaments, each containing the same amounts of impurities, are aged out at different rates, the one in which the impurities are liberated faster will show the lower total microampere-minutes of plate current. Experiments indicate that the liberation of impurities is more nearly proportional to the square of the excess emission current, or that the total impurities liberated may be expressed as $(\text{microampere})^2 - \text{minutes}$, regardless of the rate of liberation. Therefore in comparing the liberation of impurities from two or more unknown filaments this relationship has been made use of, as in the following section.

Correlation of Excess Emission and Arcs

Fig. 4 shows the results of excess emission measurements on each of four lamps whose filaments were given various cleaning treatments. The filaments for the first three lamps were taken from the groups described for Fig. 2. Filament No. 4 was similar to the control (Filament No. 2), but was further treated by sintering in hydrogen for 10 minutes at 1500°C. The excess emission as plotted was derived from the area between the total emission curve of the raw lamp and the normal emission curve of the same lamp after aging (see Fig. 3), the lamps in this case being burned for one hour at each 10-volt step. Mathematical squaring of the current was applied as described above. This emis-

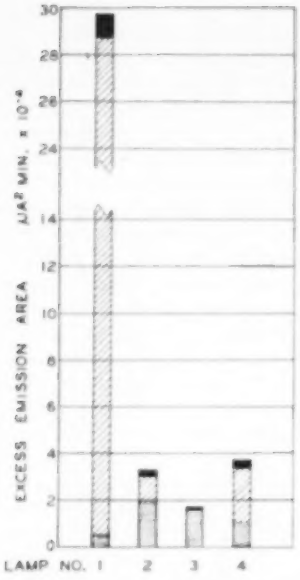

Figure 4. Excess thermionic emission as a function of filament cleanliness.

Lamp No. 1 — dirty filament

Lamp No. 2 — control filament

Lamp No. 3 — chemically cleaned filament

Lamp No. 4 — control filament thermally cleaned in hydrogen

Lower shaded portion: excess emission between 40 and 80 volts. Diagonally shaded portion: excess emission between 90 and 150 volts. Top solid portion: excess emission during aging at 150 volts.

sion is shown in Fig. 4 in three portions by shading, as measured between 40 and 80 volts, between 90 and 150 volts and during aging at 150 volts.

Good correlation is thus established between the surface cleanliness of the filament and the excess emission of the lamp. Thermal cleaning in hydrogen was shown to be ineffective. Fig. 2 has already shown the correlation between the surface cleanliness of the filament and the tendency of the lamp to arc. From these two sets of data we can therefore show correlation between the tendency of the lamp to arc and the excess emission. The theory is accordingly developed that an ionized plasma is formed surrounding the filament by the volatilization of ionized impurities from the filament, and that when this is increased to an excessive degree an arc may be established within the lamp from one filament lead to the other through this plasma.

The fact that, regardless of the degree of surface cleanliness, in no case was the excess emission completely eliminated, leads to the supposition that internal impurities within the structure of the tungsten metal are also liberated and contribute to the tendency of the lamp to arc along with the surface impurities referred to above.

Correlation of Excess Emission and Lamp Readings

It has long been an established fact that an incompletely aged lamp will show higher current (watts) and lower efficiency (lpw) than will the same lamp after complete aging. This has more or less been assumed to be caused by a change in resistance of the filament as the lamp becomes aged. However, it can be shown that the fundamental resistance of the filament does not change with aging of the lamp, but that the excess current and lower efficiency depend upon the excess emission produced by the unaged lamp.

Lamp current measurements made during the periods of lighting a raw lamp on a filament voltage and time schedule similar to that described previously (in this case 15 minutes at each 10-volt increment in voltage from zero to 150 volts) indicate that the cold resistance of the filament remains constant throughout the aging of the lamp. However, as the voltage is increased and the filament becomes incandescent, the lamp current shows an abnormal increase, (in the order of one to five per cent). This increase is defined as the current, at a given voltage, over and above the current consumed by the same lamp after complete aging when re-measured at the same voltage.

Filament temperature measurements were also made during the same successive periods of lighting the raw lamp on its schedule up through aging by means of an optical pyrometer which was focused on the inner surface of the secondary helix of the coiled coil. These results, in terms of "brightness temperature," were converted to values of "true temperature" and expressed in degrees Kelvin. These measurements indicate that, as the voltage is increased and the filament becomes incandescent, the filament shows an abnormal deficiency in temperature (in the order of 25K). This deficiency is defined as the temperature, at a given voltage, under and below the temperature attained by the same filament after complete aging when re-measured at the same voltage.

These measurements indicate that the excess lamp current and the deficiency in filament temperature observed in unaged lamps not only occur simultaneously with the excess thermionic emission, but vary in degree between lamps as the excess

thermionic emission varies between the same lamps. This correlation lends credence to the following three-fold theory:

(a) The volatilized impurities are thermally ionized and, by acting on the space charge, produce excess thermionic emission.

(b) At the same time they form a highly conductive plasma surrounding the filament, which plasma is capable of supporting a lead-to-lead current external to the filament and thus increase the total lamp current (this plasma, when present in excess, results in a destructive arc).

(c) The act of volatilizing the impurities from the filament absorbs heat, and therefore accomplishes a reduction in the temperature of the filament.

This latter has a two-fold effect. First, the efficiency (lumens per watt) is reduced with the temperature, and second, the resistance of the filament, being dependent on temperature, is decreased to the resistance value associated with the lower temperature, and the current passing through the filament at that temperature is accordingly increased. This is a true increase in filament current, but this thermal change in resistance must not be confused with a basic resistance change of the wire, which would produce a change in filament current at the *same* temperature. Quantitative measurements on these two causes of increase in lamp current show that at 50 volts, for instance, approximately half of the excess lamp current goes through the slightly cooled filament as increased filament current, and the remainder goes from one lead to the other, external to the filament, through the ionized plasma. In both cases the excess thermionic emission is associated with the increase in lamp current (watts) as well as with the decrease in temperature (efficiency) of the unaged lamp.

Conclusions

1. Excess thermionic emission is defined, and is shown to be a function of the volatilization of ionized impurities from the unaged filament. This emission increases with increasing temperature and speed of volatilization, and deteriorates with time as the impurities are expended.

2. The tendency of a lamp to arc is a direct function of the amount of excess emission present. By flashing the lamp at a medium-low voltage, a large percentage of the impurities can be volatilized from the filament without producing enough excess emission to cause an arc. Subsequent relighting at rated votage can then be accomplished without causing an arc, due to the reduced amount of impurities present and the resultant reduced emission. Chemical cleaning of the filament, by removing surface impurities, reduces the excess emission, and therefore, reduces the tendency to arc. Accordingly, a lower flashing voltage may be used with chemically cleaned filaments.

3. The high current and low efficiency readings of an unaged lamp are caused by excess thermionic emission. The fundamental resistance of the filament remains constant throughout the aging of a lamp.

DISCUSSION

HENRY F. IVEY: I have read the above paper with interest. Mr. Clapp's correlation of lamp arcing with filament cleanliness seems conclusive and of practical importance, but I should like to make the following comments on the mechanism proposed to explain the arcing phenomenon and on other points in the paper.

In describing the emission measurements, Mr. Clapp states "this current may be shown to be space charge limited, and does not increase above a certain fixed value with increasing filament temperature." Since the collector plate is operated at a positive potential with respect to the center of the filament, in increase in filament temperature (which can only be accomplished by an increase in the filament voltage) will also cause a change in the collecting voltage between the plate and the end of the filament. One would thus not expect the measured current to be independent of filament temperature in any case. Space charge considerations in such an experiment are also complicated, of course, by the complicated geometry and by the presence of the gas.

One might at first doubt that sodium would be ionized at a tungsten filament because its ionization potential (5.12 e.V.) is greater than the work function of tungsten (4.52 e.V.). However, Reimann on p. 147 of his book on "Thermionic Emission" states that "while it is true that most of the particles evaporate as ions when ϕ is greater than V_i and as atoms when ϕ is less than V_i, there must nevertheless be *some* evaporation of atoms when ϕ is slightly greater than V_i, and some evaporation of ions when ϕ is slightly less than V_i." It is also to be noted that H. E. Ives (*Journal of the Franklin Institute*, 201:47, 1926) experimentally observed the emission of Na_2 ions from a tungsten filament in an atmosphere of sodium. The impurity may not actually be sodium, of course.

Mr. Clapp's explanation of the "excess emission" involves neutralization of the electron space charge by positive ions emitted from the contaminated filament. He does not mention, however, the fact that the electron emission from such a contaminated filament will itself be greatly increased by lowering of the work function brought about by the presence of the contaminant. He apparently does not consider this effect because he believes the current to be space-charge limited. However, as discussed above, this is not certain. The increase in emission with time shown in Fig. 3 at certain stages of filament treatment could very conceivably be caused

by an activation of this kind. On this basis, one would also expect the excess emission to decrease as the contaminant is removed from the filament surface, in agreement with the observations.

Mr. Clapp also believes that an appreciable part of the difference of 25° in filament temperature for aged and unaged lamps (occuring for periods of many minutes) is caused by heat absorption arising from volatization of the impurity from the filament. Rough calculations show that this is several orders of magnitude greater than the difference to be expected from vaporization of the minute quantities of impurity that could reasonably be expected to exist. It seems fairly obvious that the known changes in crystal structure and surface appearance that occur upon heat treatment cannot be neglected in considering the cause of the change in temperature, apparent resistance, and luminous efficiency.

C. W. Pearson: Mr. Clapp's tests, showing the beneficial effect of the "clean up" on tendency to arc to be a function only of the filament, were very interesting. Equally interesting was his correlation of "excess emission" and arcs, and his explanation of high amperes and low efficiency in unaged lamps.

In a private letter from Mr. E. H. Raddin to Mr. D. E. Elmendorf, a few questions suggested by Mr. Clapp's tests were raised:

Question: Why do lamps flashed at 40 and 60 volts have a greater tendency toward arcing than those flashed at 20 volts?

Discussion: We have no explanation of this reversal in tendency to arc. Based on a very limited number of lamps, this same condition exists with our lamps.

Question: Why was thermal cleaning in hydrogen found ineffective in surface cleaning the coils?

Discussion: It might be expected that filament #4 of Fig. 4 would show less "excess emission" than the control filament #2, in that it had additional sintering at 1500°C for 10 minutes. However, Mr. Clapp's curve of emission versus time, as a lamp is flashed, indicates that after raising the flashing voltage by a small step, the emission increases and then decreases within 5 minutes to a value about the same as before the voltage was increased. Thus, additional time at any one temperature might be expected to be of little value.

It is known that on occasion, resintering is beneficial. However, when the initial sintering is adequate in regard to time, and if no additional harmful material is left on the filament after the mandrel dissolving and cleaning operations, then resintering would be expected to be of little benefit. The additional handling involved in resintering might introduce more impurities and increase the "excess emission."

Question: Can Mr. Clapp's theory be substantiated when applied to vacuum lamps, particularly of low voltage?

Discussion: In that vacuum lamps which are unaged have a higher current and lower efficiency than aged lamps, the vacuum lamps are similar to the gas filled lamp.

In addition to the above questions it would be of interest to know whether the reduction in tendency toward arcing obtained by the special cleaning process is sufficient to warrant an increase in the argon content of the filling gas.

Streamline Effects Enhanced by Light Reflections

Reflected images of long slim light sources on a glossy surface has been turned into a virtue at the Specht and Eller automobile showroom, Lykens, Pa. Alignment of the fluorescent units along the axes of the cars creates thin lines of reflections which enhance the streamlining of the automobiles on display. As the show room doubles for a show window to attract night-time pedestrians, colored lenses over spots and floodlights are used to create a pleasing picture effect at night. Installation designed by R. W. Rodgers, Pennsylvania Power and Light Co., Pottsville, Pa. office.

Performance Comparisons of Hot and Cold Cathode Fluorescent Lamps

By F. W. REUTER, JR.

The differences in construction and processing of hot and cold cathodes used in slimline fluorescent lamps, and resulting differences in lamp performance are described. Lamps with activated cold cathodes have rising voltage characteristics during life, not common to hot cathode lamps, which adversely affect efficiency maintenance and reduce lumen output of lamps operated on lag ballasts with fixed voltage inputs. Severer exhaust procedures are required for lamps having activated cold cathodes, which can reduce initial lumen output; lamps with lower initial lumens have better per cent lumen maintenance but a lower total lumen aggregate.

FLUORESCENT LAMPS are often classified as hot cathode lamps or cold cathode lamps. Categorically, the cathode has nothing to do with the arc column watts which supply the energy for the fluorescent light, and is primarily in the lamp to serve as an electron source for the arc. Electrons can be released more efficiently from hot cathodes than from cold; for this reason, less watts are used by hot cathode lamps than by cold cathode lamps, of the same physical dimensions and operated at equal currents, to produce the same amount of energy available for light output. The resulting wattage difference between cold and hot cathode lamps having equivalent diameters and arc lengths, is initially constant. 96T8 slimline lamps having activated cold cathodes initially use about 25 per cent more watts at 120 ma than those having activated hot cathodes.

Efficient cathodes do not satisfy all of the asked-for characteristics in fluorescent lamps. Life of cathodes in lamps operated on currents below 100 ma or on frequent-starting circuits is inherently much longer for cold than for hot cathodes. Consequently, slimline lamps are manufactured with either hot or cold cathodes.

Rather than apply generalizations to the differences between hot and cold cathode slimline lamps, particularly wherein the other important questions of lumens, lumen maintenance and wattage maintenance are concerned, it is the purpose of this paper to describe (1) the major difference in construction and processing of hot and cold cathodes as adapted to slimline lamps; (2) some of the effects on these cathodes of common lamp variables, particularly filling gas pressure and operating current, a-c and d-c; (3) and the resulting differences to the life and efficiency characteristics of cold and hot cathode slimline lamps operated on instant-start multiple ballasts in the laboratory.

Favorable Conditions for Experimentation

For several years, production of both types of slimline lamps was in this laboratory. Although lamps were exhausted on different equipment, all cold and hot cathode lamps used the same phosphor-coated 96T8 and 72T8 bulbs (lamp sizes to which this paper is limited), thus materially reducing one of the major variables inherent in a study of fluorescent lamps. Lamps could be made with standard parts and on standard equipment, test variables purposely introduced, and some assurance be had that differences in observed or measured results would be due to the variables alone. Advantage was usually taken of the testing section associated with the laboratory, where lamps could be operated under accurately controlled conditions. Lamp life and reasons for failure were meticulously recorded and periodic measurements of electrical and lumen values made on equipment carefully designed and adjusted to keep measurement errors to a minimum. In all, there existed a favorable opportunity for a comparative study of cold and hot cathode slimline lamps. The data given in this paper refers to slimline lamps manufactured and tested under these conditions.

Design and Process Differences

Side by side, unlighted cold and hot cathode slimline lamps look essentially alike. When lighted, the lamps with the cold cathodes have dark ends because of the differences in construction of the two types of cathodes shown in Fig. 1. The hot cathode is an activated, coiled tungsten filament, each end of which is electrically connected to and

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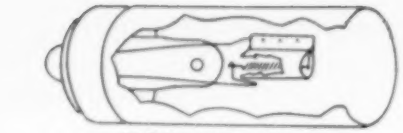
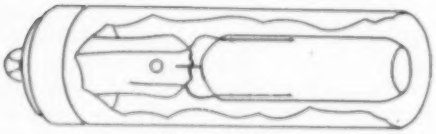


SHIELDED HOT CATHODE



COLD CATHODE

Figure 1. Typical T-8 slimline lamp cathode constructions.

supported by the two lead wires running through the lamp stem to the single contact pin on the lamp base. The shield around the cathode is supported by one of the lead wires and does not touch the coils of the filament. The primary purpose of the shield is to minimize end-darkening of the bulb caused by the gradual disintegration of the cathode during starting.

In operation, the arc comes from a hot spot on the coiled cathode. During life the hot spot, which begins at one end, gradually traverses the cathode until all of the active material is expended. When activity is lost a rise in voltage at the cathode occurs, rapidly and completely disintegrating the tungsten filament, and the lamp soon fails.

The cold cathode is a pure iron, nickel-plated thimble, approximately 1½ inches long, half inch in diameter and rolled down at the open end to leave an entrance diameter for the arc of about three-eighths of an inch. The greater length of the cold cathode reduces arc length about two inches, compared to hot cathode slimline lamps of equal over-all length. The inside of the cold cathode is uniformly coated with active material providing an activated area of approximately 15 cm^2. Three leads from the lamp stem (instead of the two for hot cathodes) are needed to support this heavier cathode.

During the initial active life of cold cathodes, the arc comes from inside the shell. There is no hot spot and the amount of cathode area used by the arc is dependent on the surface activity. During life the active materials sputter away much more quickly than the iron shell. Since life usually does not end until enough of the iron shell is sputtered away to cause lamp failure, the major portion of lamp life may be with the deactivated cathode condition, and, consequently, with lower operating efficiency, as explained later.

The methods used for mounting the cathodes and assembling the lamps for exhaust are similar enough to eliminate any serious differences between hot and cold cathode lamp performance. Exhaust methods, however, and particularly the processes used to de-gas and activate the cathodes, can manifest major differences in lamp quality. Both cathodes require heat treatment for de-gassing and to activate them with the better electron emitting materials. The term "de-gas," as used here, includes the evolution of gas resulting from the preliminary stages of decomposition associated with the compounds in which the active materials are present. For hot cathodes, it is convenient and advantageous to use resistance heating by applying voltage across the two leads coming out of each end of the lamp. The direct control of the cathode temperature by this method, combined with the excellent refractory and evaporation properties of tungsten, lend ample opportunity to attain optimum requirements for de-gassing and activating the cathode.

Cold cathodes require an indirect method of heating usually involving either high frequency induction, high voltage-high current arcing of the lamp, or both. Neither of these methods can be applied or controlled as easily as direct resistance heating, making it more difficult to treat cold cathodes uniformly. The optimum temperatures desired to thoroughly de-gas and activate cold cathodes are about the same as for hot cathodes. Complicating factors at these temperatures, however, are the higher evaporation rate of iron than tungsten, the longer time required to de-gas the larger cold cathodes, and, consequently, the greater opportunity to lose too much of the active materials and discolor lamp ends. High velocity ions from high-current, low-pressure arcing, permit lower activation temperatures than with high frequency heating alone, but the active ingredients may also be sputtered away by the ions if enough arcing time is used to thoroughly de-gas the cathodes. Variables in lamp performance and appearance, therefore, such as lumen maintenance, electrical characteristics during life, and end blackening, are apt to occur more frequently in cold cathode slimline lamps.

An associated and equally serious problem during the de-gasification and activation of the cathodes, is the removal of the resulting exhaust gases from the lamp. There is considerably more total gas released from cold than from hot cathode lamps, primarily because of the greater cathode area which

must be activated. None of the component exhaust gases is inert, and under certain ionization, pressure and temperature conditions present in the lamp during their exhaust, some of the gases can appreciably affect the coating on the inside of the bulb, resulting in a lower initial lumen output of the finished lamp. This exhaust effect is more apparent in cold cathode slimline lamps which have had high current arcing during exhaust. Test lamps from different exhaust procedures for cold cathode slimline lamps have shown as high a difference in initial lumens as 20 per cent in favor of the high-frequency induction method. Reducing the initial quantity of active materials added to cold cathodes should, and does give better initial lumen output, but does so at the expense of active cathode (lamp) life. At best, exhaust procedures needed for processing cold cathodes are more severe than those needed for hot cathodes, usually resulting in lower initial lumens for the cold cathode lamp. (The results of a typical comparison test are shown in Fig. 6 and will be discussed later.)

After the lamps are exhausted, a small amount of mercury is introduced together with a few millimeters of argon gas. Requirements for both lamp types are similar and gas pressures in the range of 3.5 to 4.25 mm are used.

Effect of Current Operation on Lamp Voltage Rise and Life

At very low currents all cold and self-heated hot cathodes operate as cold cathodes. Most of the current at the cathode in cold cathode lamps is carried by positive ions which bombard the cathode and release most of the needed electrons. According to the well-known Claude's Law for unactivated cathodes, the voltage at the cathode needed to accelerate the ions, commonly called cathode fall, or cathode drop, is constant as long as the current density does not exceed 1 ampere per $1\frac{1}{2}$ square decimeters of total cathode area. Certain materials on the surface of the cathode such as barium, reduce the cathode fall and consequently, increase the current that can be drawn from the same unactivated cathode area. If the cathode area is small, such as with the activated tungsten filaments in hot cathode slimlines, at large lamp currents, the energy in the discharge heats the cathode sufficiently to supply electrons thermionically. Further small raises in temperature greatly increase the rate of thermionic emission, so that any relatively minute area or "hot spot" can supply the needed electrons with little more cathode fall than is necessary to maintain the hot spot. Most of the current at the cathode in hot cathode lamps is carried by electrons and not by positive ions.

The hot-spotting on a slimline hot cathode occurs in a fraction of a second, because its small size and filamentary shape are designed to encourage rapid heating and thermionic emission. But the self-heated hot cathode, in low pressure type discharge devices, is still not practical until the watts input is great enough to permit a cathode fall below 20 volts, above which potential the delicate cathode begins to sputter away. Sputtering of the hot cathodes in slimline lamps occurs at operating a-c currents somewhere below 100 ma. Life at this and higher currents, nevertheless, is limited, largely because of the sputtering of the active materials during the starting cycle and their gradual evaporation from wherever the hot spot may be on the cathode. The automatic transfer of the hot spot to the most active place on the cathode, maintains the low cathode fall of the lamp until all of the active material is spent. Voltage maintenance of hot cathode slimline lamps is, therefore, practically constant to the end of life. Increasing the current from 100 ma to more than 400 ma does not materially affect life, as partially indicated in Table I. 300 ma, however, is the recommended maximum operational current of any T-8 slimline lamp, because light output is not proportionately greater at higher currents.

The cathode fall of initially active cold cathodes used in slimline lamps is about 85 volts, which is well above the sputtering potential for the active materials on the surface of the cathode. Because electron emission is drawn from most of the active surface (except at very low currents), the sputtering of the active materials from cold cathodes is accompanied by a gradual rise in cathode fall, and consequent gradual rise in lamp voltage. Fig. 2 shows the voltage rise versus burning hours for 120 ma operation of slimline lamps having cold cathodes with initially active areas of 12.5 cm^2. Increasing the active cathode area to 15 cm^2 and lowering lamp current to about 60 ma, practically eliminates all voltage rise to 10,000 hours (see Table II), provided the filling gas pressure is 4.25 mm or higher,

TABLE I.—Effect of Current and Argon Pressure on Life for One 40-Lamp Test
Slimline Hot Cathode

	Average Life—Hours*		
P mm	50 ma	100 ma	300 ma
3.5	2,700	6,700	6,600
4.5	5,500	8,000+	8,200+
6.0	8,600+	10,000+	10,000+
8.0	10,000+	10,000+	10,000+

*Test stopped at 10,000 hours.

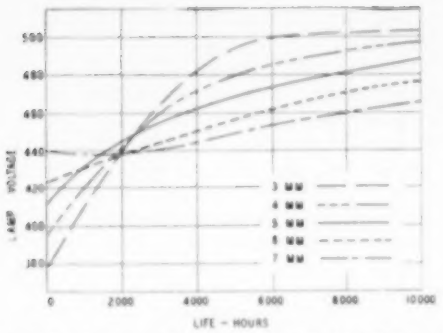


Figure 2. Cold cathode lamp volts during life. 96T8 lamps, activated cold cathodes of 12.5 cm² area. One 25-lamp test with various argon filling pressures; lamps operated at 120 ma.

as explained later. Operating these same lamps above 120 ma. precipitously increases the deterioration of the cathode, and appreciable voltage rises occur early in life as shown in Table II. All traces of the active materials are soon lost, the cathode fall rises well above the normal 165 volts for pure iron,[1] and the iron sputters away until the lamp fails to operate from the overheating of some structural part.

Operational life of slimline lamps with cold cathodes is almost immeasurably long with low current operation; even on 300 ma circuits it may take 5000 hours for the cathode to sputter away enough for the lamp to fail. Cold cathode lamps, therefore, are scarcely affected by the number of starts and stay lighted until the steady depreciation of the light output, common to all fluorescent lamps, or the voltage rise, makes it advisable to replace them. Table II shows the relationship between voltage rise, burnout life and current operation of cold cathode slimlines filled with 4.25 mm of argon.

Filling Gas Pressure

The purpose of argon filling-gas is to start the mercury discharge in the lamps and maintain ultraviolet emission at a maximum. Low pressures give higher efficiency and easier starting, while higher pressures give longer burning life and better per cent lumen maintenance. The pressure of the gas in any slimline type of lamp is, therefore, a compromise, selected for the best over-all lamp performance, as determined from long experience with many types of fluorescent lamps.

Both cold and hot cathode slimline lamps start as cold cathodes; consequently, they have the same over-all starting voltage with equal filling pressures. 750 volts was chosen as the open circuit voltage of multiple ballasts for starting 96T8 slimline lamps filled with 3.5 - 4.25 mm of argon (600 volts for 72T8 multiple ballasts). At this voltage, 96T8 lamps start reliably provided adverse relative humidity effects[2] are nullified with some starting

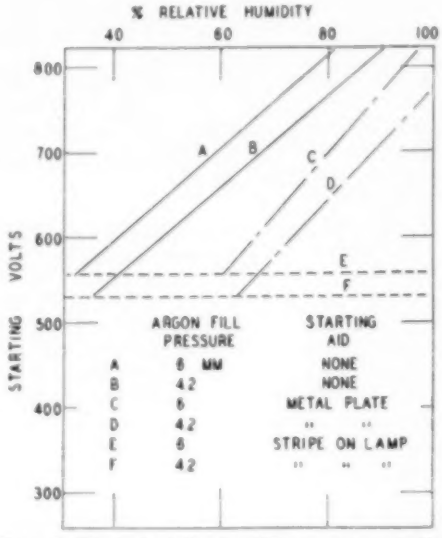


Figure 3. Effect of relative humidity on average starting volts of 96T8 hot and cold cathode lamps with 6 and 4.2 mm argon filling pressure. One test.

TABLE II.—Effect of Current on Voltage Rise and Burnout Life for One 50-Lamp Test 96T8 Cold Cathode Lamps

Argon Filling Pressure 4.25 mm

Activated Cold Cathodes of 15 cm² Area

Current Ma	3,000 Hours		5,000 Hours		10,000 Hours	
	Voltage % of 100 Hrs.	Life — % Survivors	Voltage % of 100 Hrs.	Life — % Survivors	Voltage % of 100 Hrs.	Life — % Survivors
60	98	100	100	100	102	100
120	111	100	115	100	120	100
180	130	100	135	90	135	75
240		100		66		0
300		90		22		0

aid, such as a metal stripe on the lamp or a metal fixture running the length of the lamp as indicated in Fig. 3. Even with starting aids, higher filling pressures than 4.25 mm of argon are unsatisfactory because of the varying field voltage conditions and the spread in starting voltages found between individual lamps.

Table I shows the average life of one test of hot cathode slimline lamps filled with 3.5 mm of argon and operated at 50, 100 and 200 ma. The lamps used for this particular test had an operating cycle of 3 hours on and 20 minutes off, in order to include normal loss in life due to starting effects on the cathode. Also illustrated in Table I is the increase in both life and current range for hot cathode lamps having filling pressures above 3.5 mm, but at the expense of harder starting and lower initial efficiency.

Cold cathode lamps are similarly affected by filling gas pressures above 3.5 mm. Sputtering of the cathodes and subsequent voltage-rise characteristics are progressively reduced with higher filling pressures as shown in Fig. 3; thus, extending current range and life. Slimline lamps having cold cathodes of 15 cm² active area and operated at 120 ma, however, must be filled with 7 mm or more of argon in order to effectively suppress voltage rises before 10,000 burning hours are reached. Life to failure at these higher filling pressures is very long at 120 ma. One test in the laboratory was carried to 25,000 hours before it was stopped.

D-C Operation

Quite a little interest has been shown for instant-start 72T8 slimline lamp operation on 600-volt d-c transportation circuits. Cold cathode lamps[3] are usually used for this service because the lamps on subway cars and trolley buses are subject to very

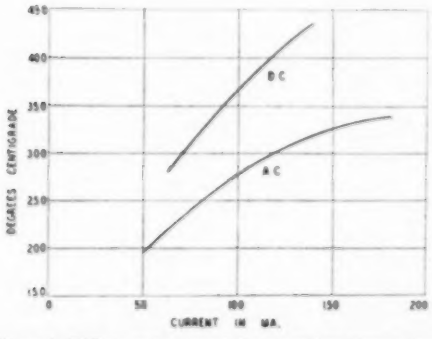


Figure 4. Difference in a-c and d-c operating temperatures of cold cathodes in T-8 lamp. Argon filling pressure 4.25 mm. One test on activated cold cathode of 15 cm² area.

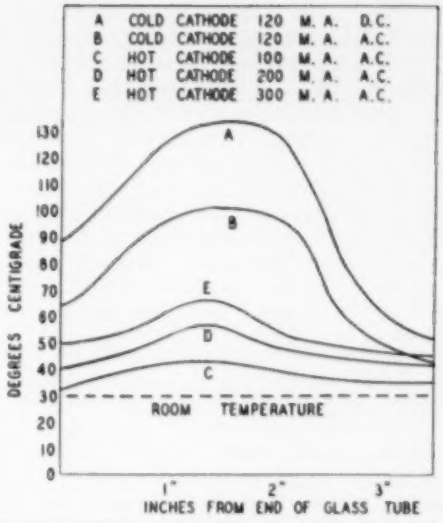


Figure 5. Bulb wall temperature distribution for T-8 slimline lamps.

frequent starting. In addition, the hot cathode construction does not have an over-all efficiency advantage on d-c circuits. The difference between lamp operating voltage and supply voltage must be taken up in resistive ballasting; thus, the total wattage consumed at a given current is the same for either slimline type.

When operated on d-c, one electrode operates continuously for long periods of time instead of alternating with the other electrode each half cycle as is the case in a-c operation. Thus, in effect, the current density at the cathode is greater, which results in faster sputtering of the cathode and, subsequently, shorter life. The effective increase in current density on d-c also raises cathode and bulb wall temperatures, as shown in Figs. 4 and 5. Temperature readings shown in Fig. 4 were taken by means of a thermocouple attached to the cathode of an operating lamp, and indicate that operation at 70 ma d-c is equivalent to 120 ma a-c, and that 120 ma d-c is comparable to operation of something over 200 ma a-c. Life tests on 72T8 cold cathode slimline lamps confirm this point, indicating the lamps should not be operated at a current higher than 80 ma d-c, if performance is to be equal to that obtainable on 120 ma a-c.

Larger cathodes, now on trial, and filling pressures higher than those used in lamps for a-c service, of course, can increase life. Higher filling pressures, however, are not always practical for the 72T8 lamps operated on 600-volt d-c circuits, be-

cause of starting difficulties in cold weather. Briefly, the operating voltage of cold lamps (40°F and lower), is much higher than for lamps at 70°F, and may be very close to the low voltages commonly found at the ends of the 600-volt supplies and during peak traffic load. Although the high voltage oscillatory kick from the d-c starting ballasts usually starts the lamps, the fixed resistance, in series with each lamp across the supply voltage, limits the current enough to prevent the lamps from warming quickly to useful brightness.

Lumens and Lumen Maintenance

Lumens and lumen maintenance in the two cathode types of slimline lamps, on a lumen per lighted foot basis, should be equal, if lamp making variables are present in the same amount and operating conditions similar. Total lumens from slimlines with the hot cathode construction should nevertheless be greater, because of the extra lighted end length, which in the 96T8 lamp size should add about four per cent more lumens. Up to the present, laboratory test data have shown hot cathode slimline lamps to have initial 100-hour lumen outputs consistently higher than can be accounted for by the extra light from the ends alone. In reiteration, the major portion of this added variance in initial lumens between cold and hot cathode slimlines is probably due to the severer exhaust requirements for the lamps having cold cathodes. Exhaust processes are steadily improving, and it is reasonable to assume cold cathode slimline initial lumens will eventually be on a lumen per lighted foot par with the present hot cathode slimlines.

Cold cathode slimlines having lumen losses due to the severer exhaust conditions, in general have had better *per cent* lumen maintenance values; mean lumens, nevertheless, are still below those of the hot cathode slimlines for any equivalent time within the life range of the hot cathode lamps. Comparison lumen depreciation curves on an absolute lumen scale against hours life, indicate that the lamps with the better lumen maintenance, have lumen depreciation rates which asymtotically approach those from initially high lumen lamps. Illustrated in Fig. 6 are the absolute lumen curves from a typical comparison test of hot versus cold cathode slimline lamps, operated on multiple ballasts with the primary voltages initially adjusted to give 120 ma lamp currents. Lamp measurements at photometry intervals also were made at 120 ma lamp current to compensate for the voltage rise of the cold cathode lamps. All of the lamps in this particular test were made from the same lot of phosphor-coated, lehred bulbs in order to eliminate

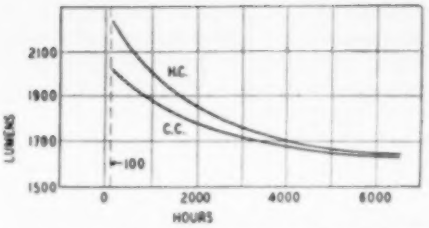


Figure 6. Lumens versus burning hours from 96T8 4500° white cold and hot cathode lamp test outlined in Table III.

as many variables as possible before exhausting the lamps. Table III outlines the electrical, lumen and maintenance test data from which the curves in Fig. 4 were plotted. Note from Table III the 6500/100 hour lumen maintenance of the cold cathode test lamps was seven per cent better than the hot cathode lamps, but that the 100-6500 hour mean lumens were approximately three per cent less.

The lumen results shown in Fig. 6 and Table III, on first thought, favor the slimlines with the hot cathodes by about four per cent, because of the extra lighted length. In this particular test, however, there was a .75 mm higher filling-gas pressure in the cold cathode lamps which should have benefited their lumen maintenance. Data from several independent cold and hot cathode lamp tests have shown lumen maintenance to improve about three per cent per mm of argon filling-gas pressure at 5,000 hours, in pressure ranges from 3 to 8 mm.

The inference was previously made that any voltage changes in cold cathode slimline lamps are re-

TABLE III.—Results from One 32-Lamp Comparison Test. Initial lumens, volts, watts, lumens per watt, and respective maintenance values and mean lumens at 6500 hours from 96T8 4500° white hot and cold cathode lamps operated on 120 ma ballasts, and measured at 120 ma.

	Burning Hours	Hot Cathode	Cold Cathode	% of HC
Lumens	100	2240	2040	91
Lumens	6500	1640	1625	99
% Lumen Maintenance	6500/100	73	80	
Mean Lumens	100-6500	1790	1730	97
Volts	100	320	390	122
Volts	6500	325	420	135
% Volt Maintenance	6500/100	101	110	
Watts	100	34	42	123
Watts	6500	34	46	135
% Watt Maintenance	6500/100	100	109	
LPW	100	66	49	74
LPW	6500	49	35	72
% LPW Maintenance	6500/100	73	73	

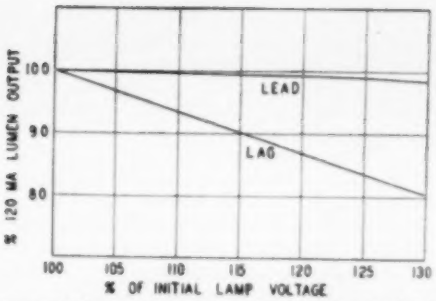


Figure 7. Lumen loss of cold cathode lamps operated on lag-lead ballasts, due to rise in lamp volts during life.

flected in the lumen output, if the lamps are operated on lag ballasts or on the lag circuit of lead-lag multiple ballasts with a fixed voltage input to the ballast. Unlike lead circuits, which maintain essentially constant current for large variations in lamp voltage, lag lamp current or lumen output is nearly proportional to proportionate changes in lamp voltage. Fig. 7 shows the per cent of 120 ma lumen output of 96T8 cold cathode lamps operated on lead-lag multiple ballasts, in relation to the per cent voltage rise of the lamps as measured at 120 ma. Inasmuch as the cold cathode test lamps used for the lumen curve in Fig. 6 had an average voltage rise of 10 per cent at 6500 hours (see Table III), and were operated on lead-lag ballasts, the realized average lumen output per cold cathode lamp in this test at 6500 hours was 1570 instead of 1625; thus lumen maintenance of the installation was 78 per cent and not 80 per cent. Continued operation of this same cold cathode test installation beyond 6500 hours, would gradually reduce the average lumen output another seven per cent due to lamp voltage rises alone.

Lumens per Watt

In the introduction it was pointed out the basic wattage difference between hot and cold cathode slimline lamps is initially constant for any length of lamp, and that 96T8 slimline watts are initially 25 per cent higher for lamps having activated cold cathodes, than for lamps having activated hot cathodes. It should follow that initial lumens per watt are 25 per cent higher for 96T8 hot cathode slimlines, and that this differential is maintained throughout the life of the lamps. There is, however, no perfect illustration of this constant lumen per watt differential between hot and cold cathode slimline lamps, unless, as shown in Table III, the cold cathode lamps have lower initial lumens and higher lumen maintenance than the hot cathode lamps to balance the rising wattage characteristic of the cold cathode lamps. At 120 ma operation, the efficiency characteristics between hot and cold slimline lamps gradually diverge with life. This efficiency divergence with life increases sharply at higher currents, and decreases at lower ones. No extended efficiency comparisons at currents much below 100 ma can be made because of the rapid increase in lamp failure of the hot cathode lamps.

The limitations in life of the hot cathode lamps at lower currents and on multi-start circuits at any current, compared to the long operational life of the cold cathode, may, for some lighting purposes, be more important than the lumen efficiency of the lamp itself. There is, therefore, a wide current range which can be served by either hot or cold cathode slimline lamps. Choice of cold or hot cathode slimlines, nevertheless, should be made with these three things in mind:

1. Lamp filling pressure is adjusted in both hot and cold cathode slimlines to give the best compromise between starting, efficiency and life and not life alone.

2. Cold cathode slimline lamps have a rising voltage characteristic during life, which increases rapidly with small increases in current operation.

3. High per cent lumen maintenance is not necessarily a measure of high mean lumen efficiency for fluorescent lamps.

The author wishes to thank many of the people at Nela Park, particularly Messrs. R. N. Thayer and A. C. Barr, for data and help in preparing this paper.

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DISCUSSION

ROBERT T. CUTLER*: The results given in this paper are very interesting, but unfortunately they are not based on the standard cold cathode lamp of the Fluorescent Association — a group which represents most all persons actively engaged in the manufacture and application of cold cathode.

The standard Fluorescent Lighting Association lamp approved by the American Standards Association is a 6mm pressure lamp, while the report is based mainly on the 4.2mm lamp.

With regard to cold cathode lamp life — from your data and on the basis of accepted practice of rating lamp

*President, Fluorescent Lighting Association, New York, N. Y.

life — then the life of a cold cathode lamp operating at 120 ma is in the order of 25,000 hours. I should like to point out that in normal commercial application this means eight years of service, which is in keeping with the actual on the job experience which we are getting.

In the past there has been a great deal of misunderstanding in the lighting industry with regard to cold cathode lumen maintenance. It is interesting to note that your test data indicates the per cent rate of light loss for cold cathode is less than that for hot cathode and at 6500 hours of continuous operation the light output is only 15 per cent less than the initial 100 hour rating—regardless of the number of starts.

Your figures on initial lumen output of the cold cathode lamps differ from tests made by manufacturers of standard cold cathode lamps. The rated lumen output of 120 ma, 93" lamp 4500° cold cathode is today 2150 lumens.

Taking this new value, and the data given in Fig. 6, we would obtain from the cold cathode lamp *1830 lumens* at the end of 6500 hours — which is above the average of the hot cathode during its life, and would be approximately *1730* lumens at the end of 13,000 hours — which is still greater than the hot cathode at the end of life, or its 6500-hour value indicated on your chart.

With regard to lamp current and brightness, the cold cathode lamp has been leading the field as a low brightness source. Your data substantiates our experience that the cold cathode lamp is an efficient low brightness source, while hot cathode lamps operate more efficiently at higher currents and consequently with higher surface brightness. This means that the cold cathode lamp results in less reflected glare and higher luminaire efficiencies.

In your paper you note the difference in lumens per watt between hot and cold cathode fluorescent lamps. This is somewhat misleading because the long life and consequent low maintenance costs of cold cathode more than offset this wattage difference and result in a most economical lighting source.

In your conclusions you state that the choice between hot and cold cathode lamps should be made with consideration of the rising voltage characteristics of cold cathode during life. I do not see how this affects the problem of application or the selection of light source used since transformers are designed with an ample voltage safety factor to operate the cold cathode lamps during their entire life.

Relighting Program in Nashville, Tennessee School Rooms

Twenty-eight Nashville, Tennessee schools now have illumination levels of a reported 35 footcandles maintained average. E. L. Bickley, director of planning, maintenance and plant operation for the Nashville Board of Education reports their recently completed relighting program involved over 7000 two-lamp (40-watt) fluorescent units. The fixtures were so located in the room that an average maintained value of 35 ft-c was obtained from the two-row installation which normally delivers 30 ft-c. The outer row of fixtures was moved in two feet, giving a 10-ft spacing between rows, and utilizing the daylight present during the regular school hours. The average level in the 28 schools before relighting was estimated at 8 ft-c.

Lighting Design for Night Driving

By D. M. FINCH

What are the engineering problems associated with lighting for night driving? Are technical solutions available to meet the illumination requirements? In most cases the problems can be readily stated but the solutions are not always obvious. In the following discussion the basic requirements for seeing under night driving conditions are reviewed and some solutions to the problems are offered.

THE AMOUNT of natural light available for seeing is continually changing throughout the day and night. As the daylight hours fade into evening, driving continues and we find the same vehicles, drivers, and roads as in the preceding daylight hours, but the driver's visibility is certainly not the same. As will be shown later, his ability to see is very markedly reduced. This one variable of *driver visibility* is outstanding in its influence on the unsafe operation of motor vehicles. Extensive accident records very clearly bear this out. It is necessary therefore for the illumination engineer to know the lighting requirements and to improve the night driving conditions in every way possible by designing adequate lighting equipment for vehicles, roadways and service facilities.

The driver's loss of visibility alone constitutes a major problem for the illumination engineer, but there are other factors that are perhaps equally important. The most important of these are the factors of driver comfort and fatigue. These factors are influenced to a large extent by the glare sources in the driver's field of view.

If adequate visibility distances and relief from glare are provided by proper illumination engineering many economics and humanitarian gains are at once apparent. First, there is the saving of life and suffering due to injuries. Second, there can be a great saving in time due to fewer vehicles being tied up for repairs. Third, many problems of congestion and overloading of traffic facilities could be partially relieved by a more efficient 24-hour distribution of the traffic load. Fourth, it is well recognized that safe operating speeds are lower under conditions of reduced visibility and could be increased by improvements in lighting. Fifth, great savings in insurance premiums would result. Improved illumination holds the key to the increased safe night use of highway facilities and offers the most effective and economical *single* solution to the over-all accident problem.

Specific Engineering Problems

How do the illumination requirements for night driving differ from other illumination designs? We find that in general the seeing requirements for night driving are fundamentally the same as in most other conventional tasks. However, the variables are in an entirely different range of values in night driving than in daytime driving. Thus many of the problems associated with motor vehicle lighting and roadway illumination appear to be unique. It will be shown that the seeing conditions on the highways at night are among the most unsatisfactory and critical that an average person encounters during the course of routine living.

The seeing task is one of perceiving relatively large objects against a low brightness level background usually with very bright lights near the object. The particular ability required of the driver is a good form sense and good minimum perceptible contrast. This requirement is not generally recognized. Most tests of driver's vision are based upon visual acuity — that is, the resolution of detail at high levels of illumination. While visual acuity is important in both day and night operation of vehicles, it is of lesser importance at night.

By *Minimum Perceptible Contrast* we mean the ability to distinguish a small brightness difference between an object and its background. In measuring this quantity, the size of the visual object in the field of view is usually taken larger than one degree of angle and therefore it fills the foveal region of the retina. The background is usually taken as a patch about 2 to 5 degrees in angle enclosing the object. The field that determines the adaptation level of the eye is generally taken as a solid angle of about 0.25 steradians (cone apex angle of about 60°) that includes the object, background and remainder of the brightness patterns.

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: Associate Professor, University of California, Berkeley, Calif.

Figure 1. Fixed lighting—East Shore Highway, Berkeley, Calif. Numbers are measured values of luminosity in lumens/ft² (footlamberts). The streaks are traces of headlamps or tail lamps.

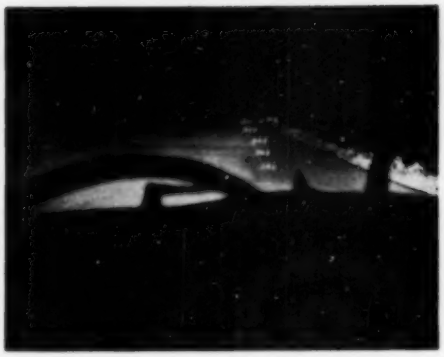

Figure 2. Upper beam headlamps—roadway near Richmond, Calif. Numbers are measured values of luminosity in lumens/ft² (footlamberts). Roadway 40 feet wide. Surface grey concrete. Pedestrian 350 feet away.

Minimum Perceptible Contrast is defined as:

$$C_{min} = \frac{L_o - L_B}{L_o} \quad \text{where } L_o \text{ is greater than } L_B \quad (1a)$$

$$\text{or} = \frac{L_B - L_o}{L_o} \quad \text{where } L_B \text{ is greater than } L_o \quad (1b)$$

L_o[6] = Luminosity of the object (lumens/ft² = footlamberts)

L_B = Luminosity of the background (lumens/ft² = footlamberts)

L_a = Luminosity of the adapting field (lumens/ft² = footlamberts)

Visual acuity is the term applied to the ability to distinguish detail. It generally indicates the smallest object that can be definitely identified; for example, the ability to read letters correctly at specified distances and with a specified probable error.

$$VA = \frac{1}{\alpha_{min}} \quad (2)$$

where VA = visual acuity

α_{min} = minimum angle between two details that can be resolved by the eye. Expressed in minutes of angle.

Both minimum perceptible contrast and visual acuity are greatly affected by the level to which the eye is adapted. The eye sensitivity decreases with lower levels of adapting luminosity.

For example, let us consider the seeing tasks encountered on the typical roadway scenes of Figs. 1, 2, and 3 and compare them to a typical interior seeing problem. Fig. 1 shows a fixed lighting installation for a roadway. It is typical in that there are many glare sources and interfering lights. Fig. 2 shows a typical roadway illuminated with the upper beam of a pair of sealed beam headlamps. Fig. 3 shows the same roadway as Fig. 2 illuminated with the lower beam of sealed beam headlamps.

In each of the seeing tasks it is first necessary to determine the adapting luminosity level of the eye. For the conditions shown in Fig. 1 the adapting

Figure 3. Lower beam headlamps—roadway near Richmond, Calif. Numbers are measured values of luminosity in lumens/ft² (footlamberts). Segmented grid has been superimposed to compute the surround factor, F_s.

[6] In this paper "Luminosity" expressed in lumens/ft² is used instead of the prevalent term "Brightness" expressed in footlamberts. The luminosities are assumed to be from perfectly diffuse sources so that $L = \pi B$. Brightness, B, is considered to have the single definition of luminous flux per unit solid angle per unit area of the source projected in the viewing direction. The units of Brightness are therefore lumens/steradian × ft² or candles/in².

luminosity would have to be taken as a weighted average of the roadway and surrounding luminosities. We can take the value from the actual brightness measurements or from calculations based upon the illumination and reflection factors.

Suppose we use the following data:

E_{ave} = average illumination on the roadway
= approx. 1.0 lumens/ft² for Fig. 1. This is a very favorable value and higher than average.

ρ = average diffuse reflection factor
= approx. 0.10 (oil stained concrete)

F_s = correction factor based upon relative areas of objects, background and surround brightness distributions, and glare sources.
= 0.80 (assumed for Fig. 1) See discussion p. 6.

then

$$L_o = F_s \rho E_{ave} \text{ (approximate)}$$
$$= 0.80 \times 0.10 \times 1.0 = 0.08 \text{ lumens/ft}^2 \quad (3)$$

which agrees reasonably well with the average of the measured values)

At this adaptation level we can get an idea of the average minimum perceptible contrast by going to such data as is shown in Fig. 4. The curve for the data of Konig[1] is perhaps the most representative since these laboratory data were taken with an illuminated background in a dark surround. For the conditions existing in Fig. 1, C_{min} is about 0.035. This means that an average observer could detect a minimum brightness difference of about 3.5 per cent. This value is for an average observer for a probability slightly greater than chance when ample time is available to search out the test patch. In other words he could correctly identify a brightness difference of 3.5 per cent about 55 per cent of the time.

For the conditions shown in Fig. 2 where the roadway is illuminated by the upper beam of the motor vehicle headlights, the adapting luminosity is determined by a much smaller area than Fig. 1. The correction factor to account for the surround, F_s, is taken as 0.85 in this case. (See page 6 for method of determination.) To obtain the adapting luminosity we may either use direct field measurements or calculate an approximate value from the design data. As a first approximation the following calculations may be used.

The roadway illumination is given by:

$$E = \frac{\text{Intensity} \times \cos\theta \times (RF)}{(\text{Distance})^2} \quad (4)$$

Where: RF is a roughness factor to account for the large number of surface elements that are not parallel to the plane of the road. RF has been found to be about 5 for broomed concrete. The headlamp mounting height is assumed to be 2.5 feet. The beam intensities are taken as design values. (From the SAE recommended practice for headlamps.)

So at 50 ft

$$E_{50} = \frac{10{,}000\ ACP \times .05 \times 5}{(50 \text{ ft})^2} = 1.0 \text{ lumens/ft}^2$$

At 100 ft

$$E_{100} = \frac{40{,}000 \times .025 \times 5}{(100)^2} = 0.5 \text{ lumens/ft}^2$$

At 200 ft

$$E_{200} = \frac{50{,}000 \times .012 \times 5}{(200)^2} = 0.07 \text{ lumens/ft}^2$$

If a weighted average for the roadway illumination, E, in the central field of view is taken as 0.5 lumens/ft² the adapting luminosity, L_o is:

$$L_o = F_s \times E \times \rho = 0.85 \times 0.5 \times 0.10$$
$$= 0.042 \text{ lumens/ft}^2 \text{ (ft-lamberts)} \quad (5)$$

At this level the minimum perceptible contrast (taken from Fig. 4) would be approximately 0.05. This means that the brightness difference between an object and its background must be at least 5 per cent in order for the person to detect the presence of the object under laboratory conditions. The difficulties in seeing are therefore about twice as great as for the fixed lighting installation if threshold data are used as a basis of comparison.

A typical interior room may be examined for comparison as follows: Assume that the average illumination equals 20 lumens/ft² (ft-c) and that the diffuse reflection factor of the walls and working plane is about 0.5. Then the adapting lumi-

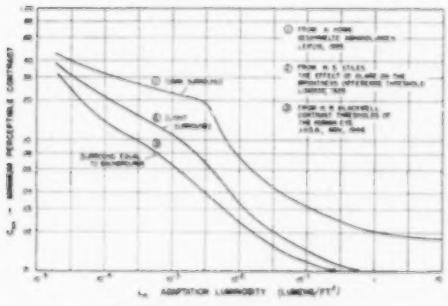

Figure 4 Contrast sensitivity.

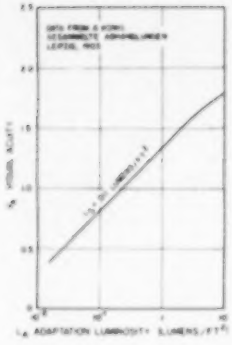

Figure 5. Visual acuity.

nosity, L_a, is approximately $= 0.75 \times 20 \times 0.5 = 7.5$ lumens/ft^2 (ft-l). The correction factor (F_s) is taken as 0.75 due to the usual brightness ratios and glare sources. Again from Fig. 4, but using curves (2) or (3) because of the lighter surrounds, C_{min} is found to be approximately 0.01. For this case a brightness difference as small as one part in 100 could be detected. If the ease of seeing is evaluated in terms of these threshold values of C_{min}, the seeing in the interior would be approximately three times as good as the roadway with fixed lights and approximately five times as good as the roadway under high beam headlight illumination

Visual acuity variations for adapting luminosities are shown in Fig. 5. For the conditions referred to above the visual acuities are approximately as shown below:

	High Beam Headlights on Roadway Fig. 2	Lighted Roadway Fig. 1	Typical Room
Visual acuity	0.55	0.75	1.6
Min. angle between two objects that could be resolved	1.8 minutes angle	1.3 minutes angle	0.6 minutes angle

These results show that for ordinary night driving conditions we need very large objects for distinct seeing. Using typical fixed street lights we would need objects about two times as large as in a typical interior room and with headlights we would need objects about three times as large as in the room to resolve the objects with equal certainty. The importance of the visual acuity data might be questioned in evaluating the roadway seeing task because the seeing of critical detail is not generally required at night. The practical situation is not this simple. We are used to seeing detail and rely upon the details of an object in order to recognize it quickly. At high levels of adapting luminosity we do this readily but at the low levels encountered on the roadway we cannot resolve the details with ease. The fact that details cannot be readily resolved at low levels makes the visibility actually worse than many test data indicate. It is not practical to isolate minimum perceptible contrast and visual acuity in the night driving task and say that only the contrast is important because most of the critical objects are large.

The application of the minimum threshold data to another of the roadway seeing tasks may also be instructive. Suppose there is a pedestrian on the highway, similar to the one in Fig. 2 or 3. We wish to know whether or not he can be seen by an average driver and what the relative visibility would be for the fixed lighting installation compared to the case where the illumination is produced solely by automobile headlamps.

The problem is to first compute the actual contrast under each lighting situation and compare it with the minimum perceptible contrast.

For the conditions shown in Fig. 1 for the fixed lighting installation, a pedestrian will be assumed and the following data will be used:

1. A pedestrian is assumed in the outside lane approximately 350 feet ahead of the car and is dressed in a gray suit having a reflectance factor of $\rho = 0.11$.

2. The vertical illumination on the pedestrian is approximately the same as the horizontal illumination on the road and is taken as 0.05 lumens/ft^2.

3. The average reflection factor of the roadway is taken as $\rho = 0.10$ and the luminosity is assumed to be uniform in the region of the pedestrian.

4. The eye adaptation level for the roadway is taken as the previously calculated value of 0.08 lumens/ft^2.

5. A surround factor, F_s, to account for the glare sources, distracting sources, and non uniform brightness patterns is taken as 0.80. The method of determining this factor is shown on page 6.

The actual available contrast for the pedestrian on the lighted roadway may be calculated from the following equation:

$$\text{Contrast} = F_s \times \left[\frac{\text{Ped. luminosity} - \text{roadway background luminosity}}{\text{roadway background luminosity}} \right] \quad (6)$$

where: roadway background luminosity is taken within a cone of 2° total angle around the object.

$$= 0.80 \left[\frac{0.05 \times 0.11 - 0.05 \times 0.10}{0.05 \times 0.10} \right] = 0.08$$

In this assumed case the available contrast is 0.08, whereas the minimum perceptible contrast from the previous calculations is noted to be 0.03.

Therefore, the pedestrian is above threshold. In this case the object could be seen by an average observer concentrating on the task and knowing that it was present. The conditions would not be adequate for good seeing.

For the case shown in Fig. 2, the pedestrian is 350 feet ahead of the vehicle and is illuminated by the upper beam of sealed beam headlamps. Several actual luminosities for the scene are shown on the photograph. These data are used directly to determine the contrast or the design data for the headlamps and roadway which could have been used. At 350 feet the pedestrian would not be in the high intensity portion of the beam of properly adjusted headlamps but the Uniform Vehicle Code specifies that pedestrians and objects shall be visible at this distance. Using the field data shown and the previous equation the actual available contrast is:

$$C = 0.85 \times \frac{0.012 - 0.011}{0.012} = 0.07$$

The threshold contrast for this situation was shown to be about 0.05 so that the task of seeing the pedestrian in Fig. 2 is a very difficult one.

For the case shown in Fig. 3 where the pedestrian is at a distance of 100 feet and is illuminated by the lower beam of sealed beam headlamps the main portion of the beam can only strike the lower 12 to 15 inches of his trouser legs. In this scene we have the foreground at relatively high luminosity but only a small part of the object at a reasonable luminosity. The remainder of the field tapers off to very low levels and blends together in a pattern of gradual contrasts. This does not make for good brightness discrimination. The brightness patterns are the same as in the technique that is applied in camouflage. The surround factor, F_s, in this case was calculated to be 0.80.

The field data on luminosities give the following actual contrasts:

$$C_{\text{lower legs}} = 0.80 \times \frac{.11 - 0.06}{.11} = 0.36$$

$$C_{\text{waist}} = 0.80 \times \frac{.08 - .05}{.08} = 0.30$$

$$C_{\text{chest}} = 0.80 \times \frac{.035 - .03}{.035} = 0.11$$

The average adaptation level for this scene has been shown to have a threshold contrast of approximately 0.06. The pedestrian's lower legs are therefor substantially above the threshold and should be readily visible. The upper portions of the man are close to the minimum perceptible contrast and are not readily seen.

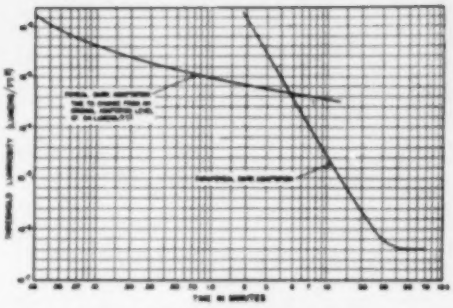

Figure 6. Time for dark adaptation.

The effect of higher reflection factors is very apparent in Fig. 3 as indicated by appearance of the white shirt collar and specular reflections from the eye glasses. The reason for recommending lighter colored materials for clothing and roadway obstacles is clearly shown.

The foregoing discussion of the threshold seeing conditions based upon contrast sensitivity and visual acuity is very general. Many of the details have been omitted because the basic data are not sufficiently complete. It has been necessary to use research data that were taken in a laboratory under controlled conditions and extend this data to cover the field conditions that prevail at night upon a highway. Such an extension is not entirely valid. The data that have been used do not include the known effects of silhouette seeing with reversed contrast, specular reflections from the objects in the field of view, non-uniform brightness patterns, color contrasts, the effect of motion and time available for seeing, the size of the sources and objects, and many of the psychological factors related to concentration, attention, experience, and mental capacity.

Furthermore, all of the contrast sensitivity and visual acuity data refer to threshold levels. It is not sufficient to use threshold levels for design inasmuch as the seeing conditions should not be comparable to "just barely seeing," but should permit "seeing with ease." The data shown may be used as a guide for checking existing installations but should not be relied upon for design purposes unless substantial safety factors are applied as suggested in the discussion on page 9.

Seeing at low levels involves the factor of time to much greater extent than at high levels. This is particularly true of the time required to reach a steady state adaptation level. The curves of Fig. 6 show some laboratory data[8] for the time to become dark adapted for the foveal and parafoveal regions

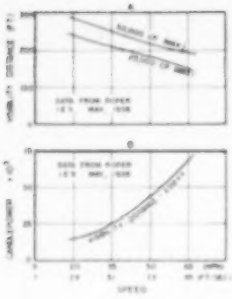

Figure 7. Visibility distance — candlepower - speed relationship.

of the retina. The adaptation rate is rapid in going from dark to light but is quite slow in going from light to dark. As shown in the figure it will take about one minute to change the foveal adaptation from a luminosity of 0.04 to 0.001 lumens/ft² and about two minutes to change the adaptation of the parafoveal region by the same amount. These changes are continuously being made by a driver's eyes at night. At the speeds that are being used in driving the time available for seeing any particular object is very much less than the adaptation time required to change from one level to another, therefore, in general the eye is not functioning at the maximum sensitivity that would obtain if the same seeing task were observed from a stationary car. Because of the limited time for seeing, a safety factor of at least two is suggested for this variable alone and should be applied to the minimum perceptible contrast determined by a laboratory experiment.

The effect of time has been studied for actual driving conditions to determine the beam candlepower required for seeing. Fig. 7 shows the results of one study.[4] In this case the car speed was varied from 25 to 65 mph, and actual visibility distances for a dummy pedestrian were determined by a number of observers. Car speed and time have a direct correlation. It may be noted that for a given beam candlepower the visibility distance decreases appreciably with speed (Fig. 7a). The converse is also clearly shown: For a constant visibility distance, more candlepower is required at high speed than at low speed (Fig. 7b).

Another important factor in night driving is the effect of glare sources in reducing visibility. Again the many laboratory researches on this subject may be applied to the night driving task. It is known that a bright source in the field of view usually has the effect of reducing minimum perceptible contrast and visual acuity.

To account for the presence of glare sources in the field of view and to evaluate the effect of the variations in the brightness patterns, a surround factor, F_s, may be computed from the physical data available. The surround factor, F_s, has been introduced previously into the determinations of threshold seeing. From laboratory experiments[2,6] it has been found that the important variables associated with F_s are: (1) the illumination at the eye from glare source, (2) the angle of each source to the line of sight, (3) the background brightness immediately adjacent to the object, and (4) the pattern of the surround brightnesses.

These variables have been related empirically to a single variable, the glare factor, Ω. The surround factor can be found using the curve for glare factor, Ω, *vs* surround factor, F_s, shown in Fig. 8.

It has been found that the best seeing conditions exist when the luminosity of the entire surround is approximately equal to that of the background. If the surround is either brighter or darker than the background of the object a larger contrast is required to detect a given object. The factor, F_s, is associated with brightness discriminations only and does not evaluate the discomfort aspects of glare sources.

The general form of the empirical formula for the glare factor is

$$\Omega p = \frac{M E_g}{x^r L_s} \qquad (7)$$

where Ωp = glare factor for a point source,

M_1 = constant depending upon the task, and the units used. For the roadway scene without opposing headlamps* $M = 87.5$.

E_g = illumination at eye due to glare source (lumens/ft²). Assumed to be produced by a point source.

x = angle to line of sight (degrees)

r = empirical exponent = 3/2

*Refer to discussion for explanation.

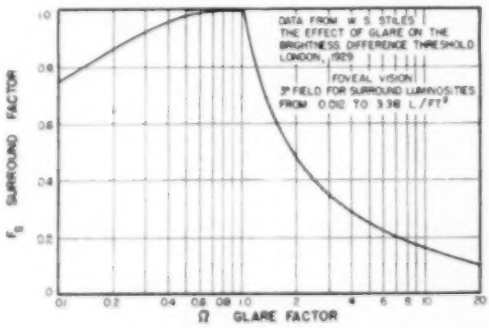
DATA FROM W. S. STILES
THE EFFECT OF GLARE ON THE BRIGHTNESS DIFFERENCE THRESHOLD
LONDON, 1929
FOVEAL VISION
2° FIELD FOR SURROUND LUMINOSITIES FROM 0.002 TO 3.98 L/FT²
SURROUND FACTOR
Ω GLARE FACTOR

Figure 8. Effect of surround.

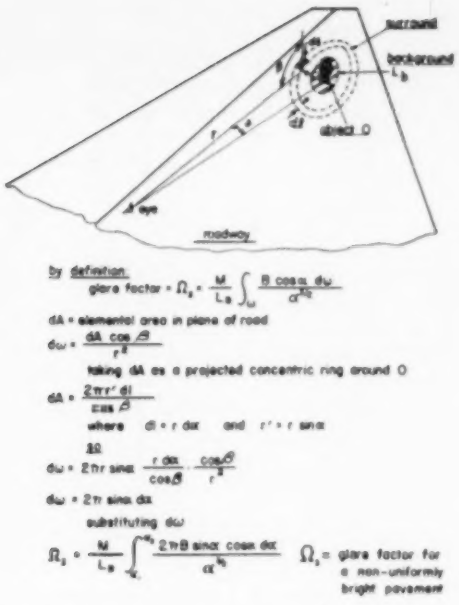

Figure 9. Glare factor for roadway.

L_B = luminosity of background of object taken as the average within a small total angle (2°) around the object. (lumens/ft²)

If the source is the roadway as in Fig. 9 and is large then

$$E_g = \int_\omega B\cos\alpha\, d\omega \qquad (8)$$

where: B is the brightness of the source in lumens/steradian × ft²

ω = solid angle of source at the eye.

So then $$\Omega_s = \frac{M_1}{L_B}\int_\omega \frac{B\cos\alpha\, d\omega}{\alpha^{3/2}} \qquad (9)$$

where: Ω_s = glare factor for a surface source.

The integral may be evaluated by expressing all the variables as functions of α. Referring to Fig 9.

$$\Omega_s = \frac{M_1}{L_B}\int_{\alpha_1}^{\alpha_2}\frac{2\pi B\sin\alpha\cos\alpha\, d\alpha}{\alpha^{3/2}} \qquad (10)$$

where Ω_s is the glare factor for a pavement surface formed by taking concentric rings around the object.

If $\alpha_1 - \alpha_2$ is small, $\alpha_{ave}^{3/2}$ may be assumed constant and placed outside the integral. Also if B is assumed constant between α_1 to α_2,

$$B = \text{const} = \frac{L_{source}}{\pi}.$$

this quantity can be placed outside the integral.

Making the above substitutions and integrating we get

$$\Omega_s = \frac{M_1 L_{source}}{\alpha_{ave}^{3/2} L_B}\left[\sin^2\alpha_2 - \sin^2\alpha_1\right] \qquad (11)$$

for a circular ring projected around the object.

The over-all glare factor for the entire scene is

$$\Omega = \Omega_{F_1} + \Omega_{F_2} + \cdots + \Omega_{s_1} + \Omega_{s_2} + \cdots \qquad (12)$$

These calculations may be made for the roadway scenes shown in Figs. 1, 2, and 3. For example the following analysis has been made of Fig. 3 to obtain the surround factor F_s.

The roadway scene may be divided into segments of annular rings as shown in Fig. 3. Equation (11) may then be applied as follows Each annular ring is divided into 18° segments (Col. 9).

Using the segment coefficient K (column 9) for each zone we compute the quantities ($K_{segment} \times L_{segment}$). Then add up all values of $K \times L$ for the scene.

TABLE I.

	1	2	3	4	5	6	7	8	9
	α_1	α_2	α_{ave}	$\alpha_{ave}^{3/2}$	$\sin^2\alpha_1$	$\Delta\sin^2\alpha_2$	$\Delta\sin^2\alpha$ (col. 6 — 5)	$\frac{M\,\Delta\sin^2\alpha}{\alpha^{3/2}}$	1/30 × (8) = K (18° segments)
a	0°	1°	0.5	.35	0.00000	0.00031	.00031	.0716	.00358
b	1	2	1.5	1.84	0.00031	0.00122	.00091	.0433	.00216
c	2	3	2.5	3.96	0.00122	0.00273	.00151	.0334	.00167
d	3	4	3.5	6.55	.00274	.00497	.00223	.0298	.00149
e	4	5	4.5	9.55	.00497	.00760	.00263	.0241	.00120
f	5	7.5	6.52	15.63	.00760	.01704	.00944	.0529	.00264
g	7.5	10.	8.75	25.69	.01704	.03015	.01311	.0443	.00221
h	10.	12.5	11.25	37.73	.03015	.04685	.01670	.0387	.00193
i	12.5	15.	13.75	50.99	.04685	.06699	.02014	.0346	.00173
j	15.	17.5	16.25	65.50	.06699	.09043	.02344	.0313	.00156
k	17.5	20.	18.75	81.19	.09043	.11698	.02655	.0286	.00143

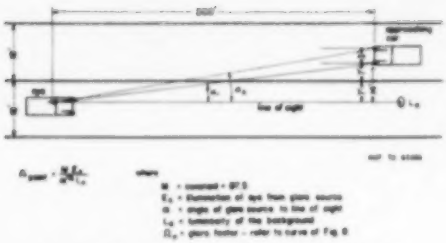

Figure 10. Glare factor for approaching car.

For Fig. 3

$$\Sigma (K \times L) = \sum_{0^\circ - 1^\circ}^{17.5^\circ - 20^\circ} (K_{sg} \times L_{sg}) = 0.0075$$

Also $L_B \cong 0.05$ lumens/ft²

$$\text{so } \Omega_s = \frac{\Sigma (K \times L)}{L_B} = \frac{0.0075}{0.05} = 0.15 \text{ (numeric)}$$

Then from Fig. 8 using $\Omega_s = 0.15$

$F_s \cong 0.80$ (numeric)—Indicates a visual efficiency of 80 per cent.

In the above instance the glare factor, Ω, is less than one and the surround factor, F_s, is not abnormally low.

Now consider the effect of very bright sources superimposed upon this scene such as the headlamps of an approaching car. For the situation assumed in Fig. 10 with the glare car 300 feet away:

$$x_1 = 2.67' \qquad x_1^{3/2} = 4.35$$
$$x_2 = 3.23' \qquad x_2^{3/2} = 5.81 \qquad (14)$$

$$E_g = \frac{I_g \cos \alpha}{D^2}$$

Assume I_g is approximately 3000 acp and $M_2 = 13.1$*

$$\text{Then } \Omega_{g1} = \frac{M_2 E_g}{x^{3/2} L_B} = \frac{13.1 \times 3000 \times .978}{4.35 \times 90200 \times 0.05} = 1.96$$

and similarly

$$\Omega_{g2} = 1.46$$

from previous calculation

$$\Omega_s = 0.15$$

So Ω over-all $= 0.15 + 1.96 + 1.46 = 3.57$

From Fig. 8, $F_{s\ \text{glare car}} = 0.30$

The single glare car seriously reduces the surround factor and causes a very substantial decrease in visibility. In this assumed case the reduction in visibility would be approximately 60 per cent. The calculations for such situations have been checked

*Refer to discussion for explanation.

TABLE II.

Glare Toward Eye (Candlepower)	Reduction of Visibility Distance Due to Glare (Per cent)
0	0
500	20
1,000	35
2,000	45
4,000	55
8,000	70
16,000	80

by experiments made with actual vehicles on typical roadways.[4] Some of the data are shown in Table II for the effect of a single pair of headlights approaching an observer on an otherwise untraveled 2-lane highway. As shown in Table II, the clear road visibility distance is rapidly reduced with increasing glare candlepower. If the glare candlepower is 3000 acp, the normal visibility is reduced by 50 per cent. This approximately checks the previous calculations of 60 per cent reduction for the assumed conditions. If the glare candlepower is 8000 acp which is the legal limit for sealed beam upper beams the clear road visibility is reduced by about 70 per cent.

Another interesting point relative to glare may be noted at this point. The maximum reduction in visibility is known to occur when a pedestrian is directly opposite a glare source. This is due to the loss of silhouette seeing as well as the reduction in visibility due to the glare source. For a typical roadway condition, the clear road visibility distance of 400 feet was reduced to 125 feet because of glare from headlights. After the glare car passed, the recovery time was a matter of several seconds which at 50 miles per hour represented several hundred feet of travel.

Another of the important factors in night visibility is essentially psychological in nature and may be termed an attention or consciousness factor. Extensive measurements were made by Roper[4] to evaluate the safety factor that should be designed into motor vehicle lighting in order to compensate for the lack of attention and other diversions that occur to distract a driver and thereby effectively

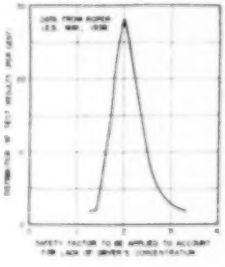

Figure 11. Concentration factor.

reduce his visibility distance. Laboratory experiments have shown that an observer has greater power to discriminate brightnesses or detail if he is concentrating on a seeing task than by inattentive observation. It is the inattentive condition that normally exists on the highways. By ingenious techniques Roper was able to obtain visibility distances for dummy pedestrians using unsuspecting observers. This was accomplished while the observers were ostensibly evaluating special headlighting systems. These data are shown in Fig. 11 and are most instructive. They show that when not expecting an obstacle, most observers have only about one-half of the visibility distance that they have if the object is known to be present, consequently another safety factor of at least two should be applied to take care of the inattention factor.

A discussion of the factors involving *visibility* alone is not generally sufficient. The aspects of comfort and fatigue are as important to many drivers as is good visibility. In fact, the accident reports that are available show that visibility, seeing comfort and visual fatigue cannot be separated.

Certain studies[7, 8] have been made to attempt to classify sensations to glaring lights in order to broadly define the limits of comfortable, objectionable and intolerable brightnesses in the field of view. Holladay[7] has done a great deal of laboratory work covering the basic relationships. The writer[8] has extended the investigation to include several particular highway conditions. The Holladay data have been reduced to the empirical formula:

$$\log K = \log L_s + 0.25 \log Q - 0.30 \log L_a \quad (13)$$

Where: K is a number assigned to the sensation of a glare source in the line of sight.

L_s is the luminosity of the glare source that is directly in the line of sight. (lumens/ft^2)

Q is the solid angle subtended by the glare source at the eye. (steradians)

L_a is the adapting luminosity of the entire field of view. (lumens/ft^2)

If the glare source is not directly in the line of sight, the effect of the angle should be included[8] but in the roadway case the angle at the discomfort distance usually need not be considered since the glare sources are several hundred feet away and separated from the line of sight by only a few feet. For the laboratory conditions used by Holladay, the following values of K are given:

1.9 boundary between comfort and discomfort

2.2 perceptibly uncomfortable

2.4 uncomfortable

2.6 between objectionable and intolerable

2.8 irritating and painful

The field conditions used by the writer[8] consisted of an observer car and a glare car on a straight two-lane concrete road without other traffic, i.e., only one glare car. The following average data were obtained for objectionable and intolerable glare:

	Objectionable glare	Intolerable glare
Illumination at observer's eyes	0.018±.009 lumens/ft^2	0.11±.05 lumens/ft^2
Distance to glare car (using 20,000 acp beam)	1040 ft	426 ft
Distance to glare car (using 50,000 acp beam)	1640 ft	674 ft

If the above data are used in equation (13) and converted to the equivalent test conditions used in Holladay's experiments, the values of K for objectionable and intolerable glare are as follows:

K (objectionable) = 2.38
K (intolerable) = 3.16
} using data by Finch

It may be noted that the value of K for objectionable glare by Finch falls between what Holladay classifies as perceptibly uncomfortable and uncomfortable. The K value by Finch for intolerable glare falls slightly above the last classification of irritating and painful. It is believed that the limits set by the writer for illumination at the eye are reasonable for the test conditions used and may be taken as a guide for design until more data become available.

The evaluation of fatigue has never been satisfactorily accomplished for roadway driving conditions even though many attempts have been made to find a good technique. Several techniques are available for laboratory studies[9] but they have not been used for field studies of driving tasks as far as the writer is aware. Among the quantities measured in the laboratory and correlated with fatigue are:

1. The decrease in the heart rate after exposure to various lighting environments.

2. The decrease in the convergence reserve of eye muscles after exposure to seeing tasks — particularly reading.

3. The increase in muscular tension after a certain time under controlled lighting. There are many variations of this scheme.

4. The increase in the rate of blinking under conditions causing eye strain.

These quantities can be used to measure fatigue for the conditions of the specific test but their correlation with night driving remains to be clarified.

Discussion and Suggested Partial Solutions

The night driving problem has been considered to be one of the perfect engineering problems because of the conflicting requirements. If one provides reasonably adequate visibility for the driver using conventional headlamps, it is not possible to avoid glare for an approaching driver. If the emphasis is on glare reduction the beam distribution is not adequate for the driver behind the lights.

This leads to a seemingly impossible design problem. No solution has been found yet that will satisfy all of the requirements. So far most of the emphasis has been on providing reasonable visibility for the driver behind the wheel with the discomfort aspects of glare receiving secondary consideration.

Any lighting design based upon visibility criteria should have a reasonable safety factor included to insure easy seeing of roadway obstacles. In the foregoing discussion it has been shown how the threshold seeing data can be used for design but threshold conditions are not adequate. The following factors are recommended for design use to be applied to the threshold seeing data:

Variables	Safety Factor
contrast sensitivity and visual acuity	2
time for adaptation time for reaction	2
inattention	2
surround glare sources without high brightness point sources	1.25

The over-all safety factor should be approximately

$$\text{Safety Factor} = 2 \times 2 \times 2 \times 1.25 = 10$$

This implies that actual contrasts and sizes of objects should be about 10 times greater than the minimum perceptible values.

The very large effect on visibility produced by small bright sources in the field of view suggests that such sources should be entirely eliminated wherever possible. Many roadway lighting installations could be designed to avoid direct glare sources. Modern safety lighting techniques show this trend with their high mounting and shielding.

In considering the present problem there appears to be a number of things that can be done to partially alleviate the very poor seeing conditions on our roadways at night. A list of such things would include:

1. Require the servicing and maintenance of the lighting equipment on existing vehicles. Surveys in California show that well over 25 per cent of the vehicles have lighting deficiencies.

2. Hold night driving speeds to a minimum. If possible, enforce lower nighttime limits than daytime limits.

3. Increase the visibility of all roadway obstacles, abutments, curbs, etc. by using white concrete and white paint wherever possible.

4. Reflectorize all possible obstacles with reflex buttons, surface materials or beaded paint.

5. Illuminate as many intersections and known hazards as possible using fixed lighting equipment.

6. Use lights of distinctive color such as sodium vapor lamps at known danger spots such as railroad crossings, complex intersections, etc. The effectiveness of this technique has been clearly proved by installations at over 100 locations in the Los Angeles area.

7. Provide safety lighting on as many miles of highway as is physically possible. Modern techniques and sources should be used to provide an average illumination of at least 1.0 lumen/ft^2 without direct glare with a distribution that will result in uniform pavement brightness.

8. Use separated roadways for opposing directions of traffic wherever possible. This will increase the angle of the glare sources to the line of sight. Physical barricades such as hedges and shrubs should be planted in the medial strip.

9. The roadway surfaces should have as high a reflection factor as possible. Occasional daylight glare should be tolerated in favor of better nighttime visibility.

10. Drivers should be encouraged to use good seeing habits. For example, a driver should not look directly at an approaching headlight; he should fixate at a point as far to the right as he can. The driver should control his dash and interior lights to eliminate bright glare sources.

11. Pedestrians should be encouraged to wear light clothing.

12. Drivers should not be encouraged by misleading information to wear tinted glasses or have fixed visors in their field of view for night driving.

In addition to these immediate steps there are some future developments that may be considered.

1. Improved highways are being rapidly introduced. Such highways will have most of the established physical elements for safe operation. In most cases lighting is one of the last considerations whereas based upon the records and the need it should have equal status with elimination of grade crossings, limiting the access and others. Several new lighting designs for streets and highways are on the drawing boards. These are based upon the design features of uniform pavement brightness and the elimination of direct glare.

2. Improved vehicle safety equipment is continually in the development stage. The new features that are particularly interesting in the illumination field are:

a. greater window area
b. improved window cleaners and washers
c. heated windshields (electric)
d. fluorescent dash lights
e. improved voltage control (a-c systems)
f. more satisfactory terminals, contacts and relays
g. improved electrical signal systems
h. improved sealed beam headlamps designed around a more satisfactory lower beam

3. There is a possibility that polarized lighting may be developed for automobile headlighting. This possible solution does not appear to be as likely as had been hoped for. Recent studies seem to indicate that the system will not be adopted in its present form.

Its future application to motor vehicles seems to offer one reasonable solution to the night driving problem. At present the technical difficulties have not been completely solved. There are also many economic and legal barriers to be eliminated before the use of this system may be considered. It is not clear at present whether or not the scheme will materialize into a practical system.

It is hoped that this discussion has provoked some serious thought about "Lighting Design for Night Driving." This subject is one that can offer more in the way of traffe safety than any other single measure.

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DISCUSSION

F. D. CROWTHER*: Professor Finch is to be highly commended for his contribution to the evaluation of the seeing task on streets and highways at night. Many of the practitioners of street and highway lighting who base their practice on combined opinion evaluation and on practical experience will welcome the highly theoretical approach made by Professor Finch. The paper shows an excellent understanding of the factors involved in providing the required improvement in night driving conditions on our streets and highways. He has quite properly brought out the distinction between lighting for visibility and design for minimum driver fatigue and discomfort.

Obviously, we cannot design street and highway lighting by making individual computations for each street as was done by Professor Finch. When we consider the required factor of safety of 10 or more above threshold or minimum, it is apparent that empirical solutions are more realistic. However, to first arrive at a datum plane to which we can relate our empirical formulas, we must have studies such as this. My recommendation to each of us interested in this field of illumination is that we give sober thought to Professor Finch's paper and that we not only read it but that we study it until we understand what it says and then we read all the bibliographical references. This alone would contribute much toward our understanding of the problems.

Now, I have some specific questions to ask Professor Finch in regard to his paper. In the example used as Fig. 1, would not the fixed lighting have shown in even more favorable contrast to the headlighting if an example were used with the fixed sources located on the outside of the pavement? Such location would have materially increased the pavement brightness, or luminosity as Professor Finch terms it, behind the object, or, in other words, would materially increase the brightness contrast.

In the formula for luminosity of the adapting field given on the third page of the paper, am I correct that this assumes uniform diffusion of the reflecting surface at all viewing angles? With the effectiveness of high angle candlepower it seems there should be a factor included for specularity of the pavement surface.

The meagre data available as to the effect of specularity on pavement brightness under the two systems of lighting, overhead fixed lighting as compared with headlighting, may justify the use of an average diffuse reflection factor in the formula used by Professor Finch. However, it may be desirable to bring out the fact that in streetlighting the specularity, or sheen of existing pavement surfaces, is utilized by directing light flux toward the motorist. The brightness of pavement between the luminaire and the observer is higher than that of the pavement beyond the luminaire. In headlighting, the specularity of the pavement surface reflects light flux away from the motorist.

In reading the paper, I had noted a few variables not mentioned which would alter laboratory data, such as absorption of car windshields, dirt on windshields, interference from light sources on the automobile instrument panel, interference from hood reflections, and interference from reflections from the windshield from light flux entering through the rear window, but in the summary of solutions, it is obvious that Professor Finch has considered these factors.

I hope this paper will stimulate other studies to expand on this excellent work. The evaluation of seeing tasks in interiors has progressed far beyond that for streets and highways. The continuation of this study would be an excellent assignment for the I.E.S. Research Fund.

The Luckiesh-Guth paper[1] suggests a course of investigation to extend that of Professor Finch, by using lower background brightness levels with multiple sources of varying brightness located on only one side of the point of fixation. Such data, if available, could easily be resolved into practical value to determine the maximum brightness levels of street lighting secondary sources at varying mounting heights in relation to the motorist observer. Such data would be of value to the progress of street lighting for comfortable seeing.

F. D. WYATT*: I would first like to commend Profes-

*General Electric Co., Schenectady, N. Y.

[1] Brightnesses in Visual Field at Borderline Between Comfort and Discomfort (BCD), November, 1949, ILLUMINATING ENGINEERING, p. 650.

*Chicago Park District, City of Chicago, Ill.

sor Finch for his courage in writing a paper encompassing the fields of highway lighting, veiling glare, and driver's reactions. These are subjects on which a great deal of work has been done and on which more exploration is needed. Professor Finch's studies should make a welcome addition to the knowledge in this field.

There are a few parts of the paper on which further clarification by the author might be desirable.

Two methods of lighting are compared: fixed lighting and headlight lighting, both with and without interfering glare from headlights of other cars. On the fifth page, the statement is made that the effects of silhouette seeing have not been considered. It is generally believed that at low levels, silhouette vision is more effective than direct vision. However, in Fig. 4, silhouette vision is given a 2 to 1 advantage over direct vision (light surround vs dark surround). As these two curves come from different sources which are 26 years apart, I would like to ask if comparable data might not be secured to give more accurate information on this point.

On the third page, a pavement reflection factor of 10 per cent is used for both fixed lighting and headlight lighting. Experience shows that the pavement reflection factor is higher with fixed lighting than for headlight lighting, especially with a continuous row of fixed street lights as shown in Fig. 1. The conclusion (on the third page) as to the relative value of the two types of lighting compared would be modified by this correction.

On the fourth page, Fig. 5, it would be desirable to define *LS* which is assumed to represent luminosity of the surround.

In equation 7, the quantity *M* is used. It would be well to show how this was derived.

A number of typographical errors occur in Table I, which should be corrected before the final printing.

In Fig. 10, some error appears in the calculation. We find:

$$x_1 = 2.68^\circ$$
$$x_2 = 3.25^\circ$$
$$E_0 = .0332$$
$$\Omega_{x1} = 4.20$$
$$\Omega_{x2} = 3.14$$
$$\Omega \text{ overall} = 7.49$$
$$\text{Reduction in visibility } 80\%$$
$$F_s = .20$$

The need of a safety factor of ten for the variables listed indicates that human vision and reactions can not yet be stated by precise formulae.

The paper ends with a very excellent list of 15 recommendations for improved night visibility and hence a reduced night accident rate. To this list I would suggest two additional items:

1. Eliminate drunken drivers from the highways by legal definition and enforcement.

2. Secure enforcement by both police officers and the courts of traffic regulations.

If all of the objectives are attained, it would be expected that large reductions in the night highway accident rate would be gained. I fear that results will be secured only after a long and painful education of the general public.

Further studies of the type presented by Professor Finch should be very definitely encouraged.

WILLARD C. BROWS*: I feel that I can qualify as a discussor of this subject not only from my past experience in this field but from a practical standpoint: because I drive upward of 6,000 miles each year *at night* ... much of this cross-country. So I have been particularly interested in Professor Finch's well-organized analysis of the factors affecting the headlighting problem. He is bold in his integration of theoretical and empirical data with test work on the road by himself and others. We need more of this.

The author speaks of the need for the driver at night having a well developed "form sense"... that is, the ability to make out unknown and unanticipated objects, at very low brightness contrasts, and to do this in a split second. To my mind, with our present headlighting, this ability marks the difference between the skilled and safe night driver and the average driver who sooner or later runs into trouble. The former picks up all sorts of vague, difficult-to-identify "shadows," and acts on them instantly; whereas the latter does not notice them at all until it may be too late.

Professor Finch says that at 350 feet, with the upper beam, a pedestrian would not be in the high-intensity portion of the beam. Perhaps the roads are smoother in California, but I submit that at normal speeds on a road anywhere in the East, the normal bouncing of the car and the consequent up and down movement of the high-intensity portion of the beam do cause it to strike the pedestrian. Hence, Professor Finch's point strikes me as being on the conservative side. But his treatment helps to emphasize the fact that at best conditions are far from satisfactory.

I do not think we have to *measure* fatigue caused by difficult seeing conditions to prove its presence. Just make a night drive under conditions when seeing is very difficult ... say, with light rain and traces of fog ... and see how you grip the wheel tighter and tighter, see how soon you tire. But I agree that quantitative data would be helpful, and would perhaps direct more attention to this part of the problem.

Under recommendations for future developments Professor Finch mentions "improved sealed-beam headlamps designed around a more satisfactory lower beam." I assume that this more satisfactory lower beam is one which provides increased seeing distances, with preferably less glare than at present. Unless means can be found to insure *exact* aiming of all headlamps, any increase in the lower beam candlepower directed near the horizontal (which is necessary for added seeing distance) will surely result in increased glare to approaching drivers. And even with exact aiming, a distribution of this type (with more candlepower at or near the horizontal) will cause additional glare on rough or rolling roads and on curves.

Some reduction in glare for perhaps 50 feet or so

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before meeting could be effected if the direct filament candlepower were shielded—such as by a non-reflecting shield on the end of the bulb or by a non-reflecting cap over the filament in the case of the all-glass sealed-beam units.

My observation has been that what we would like, in our own case, is about the equivalent of the upper beams from two pairs of sealed-beam headlamps. Twice what we have now. Yet we would like to have the approaching driver use the equivalent of parking lights. Short of something like polarized headlighting, there seems to be no practical means of accomplishing such an ideal objective. But that is another story.

In the meantime it appears that the best we can do to help improve matters is by following the list of twelve suggestions made by Professor Finch to which I might suggest one more that he no doubt considers obvious, *viz:* always use the lower beam when meeting other vehicles. This practice would be further encouraged if the car manufacturers were to improve the present upper beam indicators.

J. W. Arch Bollong*: This author poses the question "What are the engineering problems associated with lighting for night driving and the technical solutions available to meet these specific requirements?" The basic requirements for seeing under night driving conditions are reviewed and some solutions offered, starting out with an analysis of the existing roadway brightness and its patterns.

The author gives six apparent gains from an economic and public-safety standpoint, as follows:

1. Prevents night fatalities and injuries.
2. Timing saving, due to less property damage.
3. Congestion relieved by 24-hour distribution of traffic load.
4. Safe speeds can be increased.
5. Insurance rates will be lowered.
6. Most effective and economic single solution to the overall accident problem.

Three typical situations are set up for comparison purposes, namely:

1. A typical highway with fixed luminaires.
2. An unlighted highway lighted by upper beam of a sealed-beam headlight.
3. The interior of a typical room.

The statement is made that the data presented does not include the known effects of reversed silhouette, specular reflections from objects, size of objects, etc.

Under solutions, the statement is made, first, that if adequate visibility is provided by headlights, then glare is produced for the approaching driver, and second, that a safety factor of ten should be used in modern street lighting design.

Not being an ophthalmologist dealing with the science and treatment of the structure and functions of the eye, it would be presumptuous on my part to discuss these features of this very fine paper. As a traffic engineer, then, and knowing that modern traffic safety lighting is one of the tools which the traffic engineering profession is just beginning to use, certain practical points covered by this paper are here brought out.

Benefits — We can agree with all of the benefits except No. 3 and No. 6. In No. 3, relief of congestion benefit by 24-hour distribution is not true. We all know that modern work hours are such that congestion occurs during morning and evening peak hours, and that the American working time in industry is not spread out over 24 hours. The graveyard, or night shifts, are always the lightest. True, modern traffic safety lighting will greatly assist in the peak hours in the evening. However, for the balance of the hours of darkness, good lighting assists in lowering the fatality and injury rate only.

In No. 6, the statement is made that good street lighting with proper distribution and at such heights as to eliminate glare is the most effective and economical single solution to the overall accident problem, which I believe is somewhat overstated from a traffic engineering standpoint. It is one of the tools.

Under typical situations, No. 1 refers to lighting on the East Shore Highway at Berkeley, California. This example is not a good illustration of modern traffic safety lighting, as is evidenced by the illuminometer readings taken. Heights of the luminaires are not given. Evidently incandescent lamps are used. Mercury vapor lamps would have given much greater lumen output and greater silhouette.

The statement is made that the data used does not include the known effects of silhouette seeing with reversed contrast, specular reflection and other similar conditions. The question is — why not?

Referring to the light beam of the headlight and the glare produced, proposals and models have been made for controlling this high beam by means of a photoelectric cell switch on each car.

Under alleviation of poor seeing conditions, the author has outlined 12 very fine methods, all of which we agree with.

Official state or urban testing stations are one of the answers to compulsory use of properly aimed headlights.

The insertion of reflecting mediums in the top of blacktop pavements lends greatly to specularity.

One-way operation of traffic removes the glare of the approaching headlight, as all vehicles are headed in one direction.

And lastly, modern traffic safety lighting design is very thoroughly covered by the American Standard Practice for Street and Highway Lighting, sponsored by the Illuminating Engineering Society and adopted by the American Standards Association, the Institute of Traffic Engineers and the National Safety Council. Compliance with these standards when designing and erecting modern traffic safety lighting will solve many of the problems posed by this paper.

L. J. Schrenk**: This paper is timely, well prepared, and no doubt will start some serious thinking. The author has set up a new approach to the solution of the major problem in night traffic safety, that of providing fast and easy seeing.

In setting up some solutions to the basic require-

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**City of Detroit, Michigan.

ments for seeing while driving under artificial light, the author substantiates the light intensities that have been recommended by Mr. Simpson, who based his findings on accident data obtained on highways lighted with various intensities.

He also substantiates the intensities determined in Detroit from the records of fatal traffic accidents taken from thoroughfares lighted with an average illumination of .15 lumens per square foot up to 1.25 lumens per square foot.

Studies were made on some 350 miles of streets under various degrees of illumination over a period of four or five years involving several hundred fatal accidents.

The fatal accident rate decreased as the lighting intensity was increased to a point of approximately .6 lumens per square foot. The curve then starts to straighten out and approaches a straight line, almost paralleling the daylight traffic rate at lighting intensities beyond 1.25 lumens per square foot. These studies pointed out quite conclusively that thoroughfares lighted with intensities of approximately one lumen per square foot (fairly evenly distributed along the pavement) provide reasonably safe seeing conditions.

Lighting greater than one lumen per square foot can be justified as a safety factor or white-way lighting in main business section. I feel the author should be congratulated on the thoroughness of his paper and his fundamental approach to the problem.

LEWIS W. CHUBB*: It is gratifying to note increasing attention being given to the problem of night visibility on the highway. Professor Finch has examined the problem from the standpoint of highway lighting by fixed installation and by headlighting using the present system of beam control. His mathematical treatment yields certain safety factors calculated "to insure easy seeing of roadway obstacles." The overall safety factor is estimated at "approximately 10."

Quite properly, mention is made of the possibility of using polarized headlighting, although the bibliography does not contain reference to National Research Council's Highway Research Board Bulletin No. 11 dealing with the performance of this system, and discussing the viewpoints of the automobile industry, Polaroid Corporation and General Electric Company.

These groups cooperated in an investigation covering a period of about 10 years, and while it is true that the automotive industry has recommended "against adoption at this time" (November, 1947), that fact alone would not support Professor Finch's conclusion that "This possible solution does not appear to be as likely as had been hoped for," and that "Recent studies seem to indicate that the system will not be adopted in its present form." As a matter of fact, at the conclusion of these "recent studies," the Chairman of the industry committee stated to the nation's press that he knew of no other solution to the problem on the scientific horizon and that it was, in the final analysis, a question of the public's wanting it enough to demand it.

In view of the foregoing, it is submitted that "present . . . technical difficulties (which) have not been completely solved" do not exist as a bar to immediate adoption, nor is there any question as to whether the plan "will materialize into a practical system." A practical system has already been developed and tested. Not barriers, but the usual problems, legal and economic, may attend its immediate adoption, but these in no way affect the practicality of the system.

This discussion of one phase of the subject investigated by Professor Finch is intended to make clear the technical availability of a practical polarized headlighting system which will improve night driving safety and which may reduce to unity most of the safety factors recommended for lighting design by the author.

D. M. FINCH*: Regarding the optimum location of the street lighting luminaires shown in Fig. 1, it would be possible to relocate the luminaires on the edge of the pavement to increase the visibility of pedestrians. However, the center mounting is frequently used and this example is merely typical of installations of center mounted luminaires. The formula on the third page includes a term covering the average diffuse reflection factor. This is used because better data on the reflectances of pavements in the specific directions involved in street lighting or headlighting are not available. A proper value of reflectance should include the specularity of the surfaces. It is hoped that present researches on reflectances will provide the required specific data. As Mr. Crowther points out there are a number of other variables which are not included in the analysis. It would be desirable to include such variables but the data available on the absorption of windshields, dirt on windshields, the interference effects of interior lights and hood reflections are very meagre indeed and are not usually available for use in design.

Replying to Mr. Wyatt, in most analyses of this nature it is necessary to make many assumptions and usually over simplification of some of the concepts is a result. It is recognized that silhouette seeing plays an important part in night driving and that it was not considered in the examples cited. The problem would be to determine how the lights beyond the object affect the background luminosity of the object. This might be done analytically but would ordinarily require so much time and effort that it would not be considered practical. I have not attempted to include silhouette seeing for this reason. Mr. Wyatt's comments on the inadequacy of the reflectance data are very appropriate. The comments made in reply to Mr. Crowther apply equally to the discussion of Mr. Wyatt.

The questions raised regarding the computations and the constant, M, in Equation 7, need clarification. Equation 7 refers to the relationships among the important variables associated with glare. Stiles in Reference 2 has shown how a glare source is equivalent to a change in the over-all surround brightness. Moon, Reference 6, has taken this data and indicated how it might be applied to a non-uniform surround brightness. In the latter case the constant, M, is determined so that

*Polaroid Corp., Cambridge, Mass.

*Author

the integral shown in Fig. 9 will equal $\frac{1}{M}$ when the surround brightness is uniform and equal to the background brightness. I have calculated the constant, M, to be equal to 87.5 for the conditions on the roadway where the brightness is due to headlamps alone and there are no other glare sources present. The same constant, however, should not be used for the calculation of the glare effects of individual lights as shown in Fig. 10. Therefore, there were errors in the original printing for the calculations referred to the conditions for Fig. 10. I have made the corrections in the calculations of the angles and have substituted the original value for the constant, M, of 13.1 as given by Stiles and Moon. In this case the calculated reduction in visual efficiency would be 70 per cent instead of 60 per cent as first calculated. The errors in Table I have been reviewed and corrected in this printing.

With reference to Willard Brown's discussion, the normal aim of the center of the beam of a sealed beam headlamp is 3 inches down in 25 feet. A tolerance of within 3 to 6 inches down is accepted by most enforcement agencies. Thus with an average mounting height of 30 inches and normal aim the center of the beam would strike the roadway 250 feet ahead of the car. This would reduce to 125 feet for a 6-inch tilt. Of course, loading in the rear seat and trunk and road roughness will alter the aim at any particular time but the designer must use some representative average condition. Thus for purposes of analysis I have assumed the average static condition.

The desirability of a more satisfactory lower beam is apparent to even the infrequent night driver. The professional night driver, such as the truck and bus operator, is very insistent that conditions should be improved. Studies show that on major trunk highways and around centers of population where most of the vehicle-miles are generated, at least 75 per cent of the night driving must be done on the lower beam. The low beam should, therefore, be the principal beam for design purposes. If compromises in design are necessary because two filaments are in the same compartment the sacrifices should be in the upper beam since beam control is not as necessary on an open road as when encountering other vehicles. This procedure would be just the opposite of present design practice.

The light distribution in the lower beam could be modified extensively and still come within established specifications, so the manufacturers do not need to feel that the design is frozen. The end objective should be to provide the most uniform roadway brightness pattern ahead of the vehicle as possible. This is not attainable under all roadway conditions but should be the ultimate goal. At present, under most conditions, too much light is projected too close to the car. An asymmetric distribution is suggested in which more light is placed on the right hand side of the roadway. Other modifications are also possible, such as, the filament cap referred to by Mr. Brown. This would serve two purposes, namely, (1) eliminate the uncontrolled direct rays from the filament that are a source of annoyance to approaching drivers and, (2) eliminate many of the rays at large angles above the horizontal which are very objectionable in fog, rain or dust. The prism facets on the lens can also be treated to remove stray rays or the prisms can be inverted to accomplish the same purpose. Other changes are also possible and have been discussed with design engineers.

The fact that so many people both at home and abroad are so critical of our present lower beam should be the signal that more extensive research and development is necessary on this beam.

The comments of Mr. Bollong are very helpful and his criticisms are well taken. Several statements should be made, however, in reply to the points raised.

Regarding the relief of congestion, the paper merely suggests that *partial* relief of many facilities could be effected by a better distribution of the traffic load. This will automatically occur when operating conditions on a roadway become known to be comfortable and safe at night.

The paper refers to improved illumination on roadways as the most effective *single* solution to the overall accident problem. This does not refer to street lighting alone as installed in the conventional manner but does mean improvements in the whole field of illumination including safety lighting, motor vehicle lighting, roadway delineation and other phases of this profession which contribute to better visibility at night. It has been clearly shown by many studies that improvements in night seeing conditions have more to offer in reducing accidents than any one other single remedial measure.

The fixed lighting installation in Fig. 1 is an example of *better than average* conditions on our roadways at night. The photograph is probably misleading in its rendition of actual conditions. The lighting units are 10,000 lumen, sodium vapor luminaires. This roadway is one of the approaches to the San Francisco Bay Bridge. Mr. Bollong's observation that this obviously is not a good example of modern traffic safety lighting, because the readings are too low, is a point that certainly needs clarification. The readings shown are brightness values and not illumination values. This is further evidence that it is not sufficient to prescribe illumination alone but requires a knowledge of the reflection characteristics of the surface in order to determine the visual appearance of the roadway.

The data do not include the effects of specular reflections, color contrast, reversed contrast and motion because, as far as I am aware, there are no techniques available for including them in the problem. These effects are present and some will aid while others will detract in seeing specific objects, but the degree to which they affect conditions is not now determinable.

I would heartily endorse the adherence to the ASA Recommended Practice for Street and Highway Lighting as mentioned. It must be recognized, however, that these standards do not represent the ultimate in good seeing conditions. It is hoped that the reduction in visibility due to the glare sources will be seriously con-

sidered and that the desirability of having a uniform pavement brightness pattern will not be overlooked.

Mr. Chubb has brought up some interesting points regarding the possible use of polarized lighting for motor vehicles. I will have to agree with Mr. Chubb that at the present time I do not know of any complete solution to the automobile headlight problem which will permit roadway obstacles to be adequately revealed to a driver and, at the same time, not cause his headlights to interfere with the vision of an approaching motorist. Nor do I believe that the polarized lighting system available at the present time will adequately solve the problem. Even if one assumes that a complete conversion of the lighting equipment could be effected within a reasonably short period of time, there would still remain many problems associated with the satisfactory use of the polarized lighting systems. The depolarization of windshields, depolarization due to improper installation, the crown effect of roads, potential failures of equipment, the misuse of the analyzer or glasses, the loss of warning halo on curves and hills, and the impracticability of using the system on small vehicles (motorcycles, motor scooters, bicycles, etc.) all constitute serious design deficiencies that are yet to be solved before one can agree that all of the engineering features are satisfactory. The interim period during a change over to the polarized system would also pose many problems for the motorist as well as the engineer and enforcement official.

I would be one of the first ones to support and encourage the use of polarized headlighting on motor vehicles if I was personally convinced that the technical problems were at present completely solved.

Romey's Market, San Francisco—A Planned Lighting Winner

One of the winning installations in the recent Planned Lighting Competition sponsored nation-wide by General Electric, was the relighting of the San Francisco market shown below. Awards for the job went to C. L. Daly and C. M. J. Wood, lighting specialists for the Pacific Gas and Electric Co., San Francisco. Designed to provide a maintained level of 45 ft-c on the horizontal plane at 36" above the floor, actual readings after 1000 hours were over 60 ft-c average. Luminaires employed were semi-direct commercial fluorescent fixtures on 300 ma ballasts, with hinged louvers, using both 4500K and 3000K T8 fluorescent lamps (two per fixture) mounted at 16'6" for the two outside rows and 13' for the inside rows. Recessed swivel cans employed 150-watt R40 spot lamps mounted at 14'6", and recessed sockets used 150-watt R40 flood lamps at the same height. The floods and spots were set into openings which were formerly used with 200-watt glass reflectors. Illumination levels on the sloping plane of the meat cases were 60 ft-c horizontal.

Lighting for Bakeries

Prepared by the Sub-Committee on Lighting in Bakeries of the Committee on Lighting Study Projects in Industry, Illuminating Engineering Society*

Preface

In October 1946 the Council of the Society appointed a committee "to study the lighting requirements as related to the processes in bakeries, develop suitable lighting and report thereon." This report is the result of studies in a variety of bakery establishments, and gives the minimum quantities and qualities of illumination necessary for efficient and economical production.

COMMITTEE ON LIGHTING IN BAKERIES

F. J. Vodicka, *Chairman*
W. B. Bradley
G. C. Fowler
R. M. Schramer
J. C. Weeks

1. Introduction

1.1—*Visual Tasks in Bakeries*—Although there are many different types of commercial bakeries, production processes are essentially similar regardless of the size of the installation or the products manufactured. Surveys of a number of bakeries varying in size from small retail shops to large wholesale establishments manufacturing a variety of products revealed that a few operations require critical seeing. Many hand operations are of routine nature and done almost automatically with no close attention to detail. The rate of production is thus controlled mainly by manual dexterity and the condition of the working equipment, tools, and materials.

1.2—*Sanitation, Safety, and Morale* — **(a)** Besides illuminating the task good lighting is an aid to sanitation, safety, and morale. Cleanliness, of great importance in all food-producing establishments, is far easier to maintain in well-lighted interiors. (Experience indicates that dirty conditions tend to develop under low levels of illumination.)

(b) In bakeries a large part of production areas is taken up by the equipment, including tray trucks, racks, mixing bowls, etc. Good overall illumination is necessary to reduce injuries due to congestion in such areas. Adequate lighting also enhances the safety of employees operating moving machinery, working adjacent to hot surfaces, and handling hot pans.

(c) Many routine bakery operations tend to become monotonous or depressing. However, the pleasant atmosphere created by good lighting helps keep employees cheerful and alert. High morale of the working force is especially important in bakeries since the morale is depended on largely for inspection of the product during production and before shipping and selling.

2. Summary of Lighting Recommendations

2.1—*Quantity*—The general lighting equipment should be laid out to produce uniform illumination of the level recommended in Table I. A uniform level of illumination makes possible the most efficient arrangement of machinery and better utilization of floor space. Supplementary lighting is required where the general lighting system is not adequate for a particular seeing task.

2.2—*Quality*—The luminaires should be placed relative to the machinery and work benches so that there are no shadows on the work surfaces and no reflected glare from machinery, scale dials, polished metal parts, specular tile wall coverings, etc. See Figs. 5 and 6. All lamps should be well shielded to prevent direct glare.

2.3—*Environment* — Pleasant, colorful surroundings make workers more cheerful and contented, while color used in accordance with the principles of visual perception is a valuable contribution in seeing the task. General recommendations are made as follows:

(a) Colors for general use should be fairly light and are best applied in plain all-over fashion.

(b) Pleasant colors should always be selected and where definite hues, such as green or blue are desired very light greyed tones should be used.

(c) Large areas of strong colors, such as bright red, yellow or green, should be avoided.

(d) While the ceiling should be matte white so that the maximum light will be reflected, walls should not be white, as they then become brighter than the work task, and consequently uncomfortable. Reflectances of 50 to 60 per cent are recommended.

(e) Machines should be fairly light in color to reflect more light and to reduce brightness contrasts in the line of vision

TABLE I.—Lighting Levels at the Work.

Current Recommended Practice

Area	Footcandles Maintained in Service
Mixing Room	20
Face of shelves (vertical illumination)	10
Inside of mixing bowl (vertical mixers)	50*
Fermentation Room	10
Make-up Room	
Bread	20
Sweet yeast raised products	30
Proofing Room	10
Oven Room	20
Fillings and Other Ingredients	20
Decorating and Icing	
Mechanical	20
Hand	50
Scales and Thermometers	30
Wrapping Room	20
Storage Room	10
Shipping Room	20
Offices	30-50**
Reception Rooms	10
Washrooms, Stairways	10
Halls, Corridors, Passageways	5

*Requires supplementary illumination.

**I.E.S. Recommended Practice of Office Lighting.

*Approved by the Council of the Illuminating Engineering Society, May, 1950.

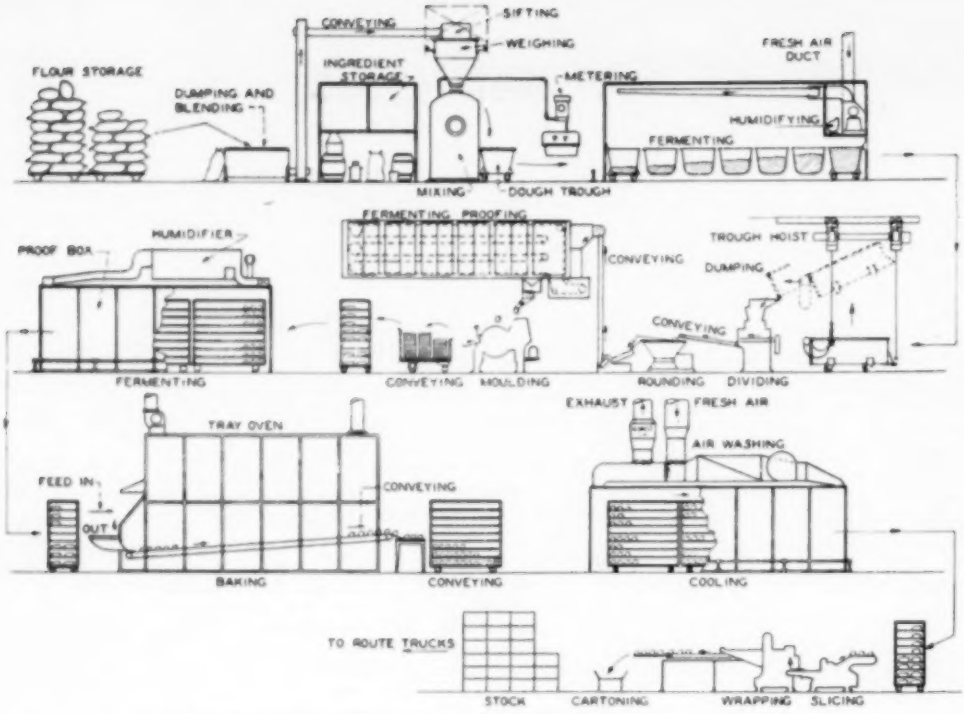
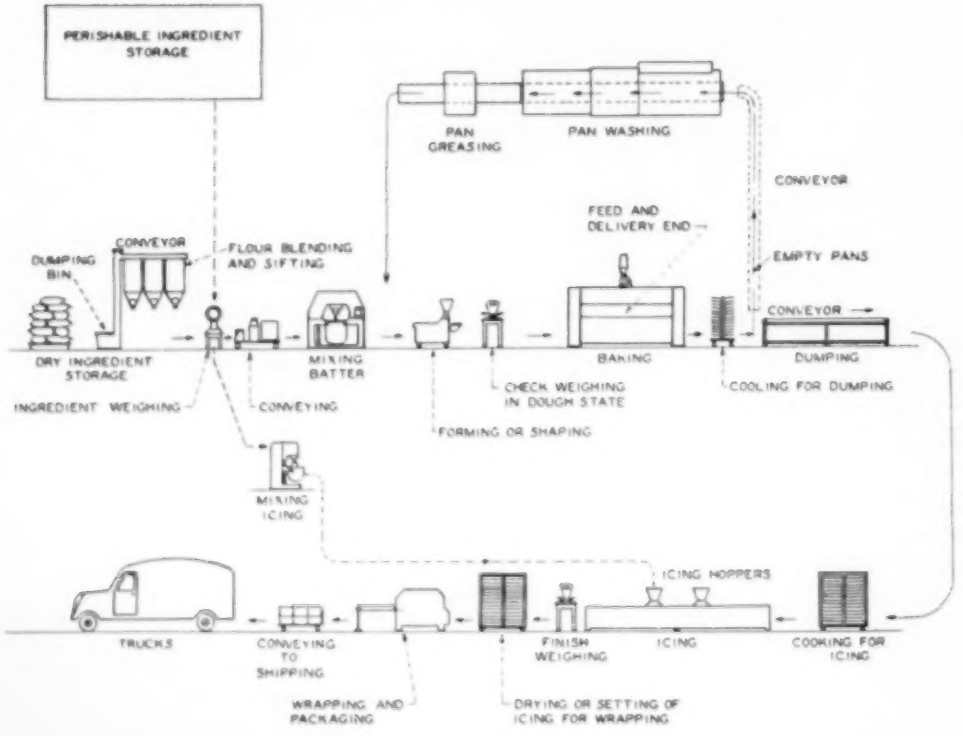


Figure 1. Flow charts: a. (above) bread, b. (below) cake.



for ease of seeing. Reflectances of 25 to 50 per cent are recommended.

(f) Backgrounds to work tasks should be of a carefully chosen color, and usually of a lower brightness, approximately one-third that of the task.

(g) Contrast obtained by hues of somewhat similar brightness is more effective and restful than contrast in brightness alone.

3. Artificial Lighting

(a) The maximum use of natural lighting should be encouraged for the bakery processes performed during daylight hours. However, since all bakeries operate at least one night shift and during the winter months adequate natural light is available for only a few hours per day, an artificial lighting system which will produce the illumination levels specified in Table I should be provided.

(b) The value of a good general lighting system is lost if only those units in the immediate vicinity of the work are turned on. This is often the result when luminaires are controlled by individual pull chain switches, in which case the spotty illumination tends to cause glare. Deep shadows caused by irregular lighting patterns tend to produce hazards. For this reason switching should be so arranged that the recommended level of general illumination is maintained in the entire room. A typical arrangement of luminaires for general illumination as well as a recommended method of switching is shown in Fig. 2.

(c) Control for supplementary lighting units should be located at the work position.

4. Daylighting

(a) In the baking industry every effort is made to provide as much natural light as possible. In some old buildings production equipment is placed close to the windows, resulting in a crowded condition which impedes production and leaves large parts of the rooms unused or for storage. The present trend in bakery construction is toward the use of glass block walls and large windows wherever possible.

(b) Windows can be treated as any other type of light source and the requirements for good lighting (*e.g.*, adequate illumination, proper distribution, freedom from high brightness differences (ratios), etc.) applied. Similarly, the factors affecting lighting de-

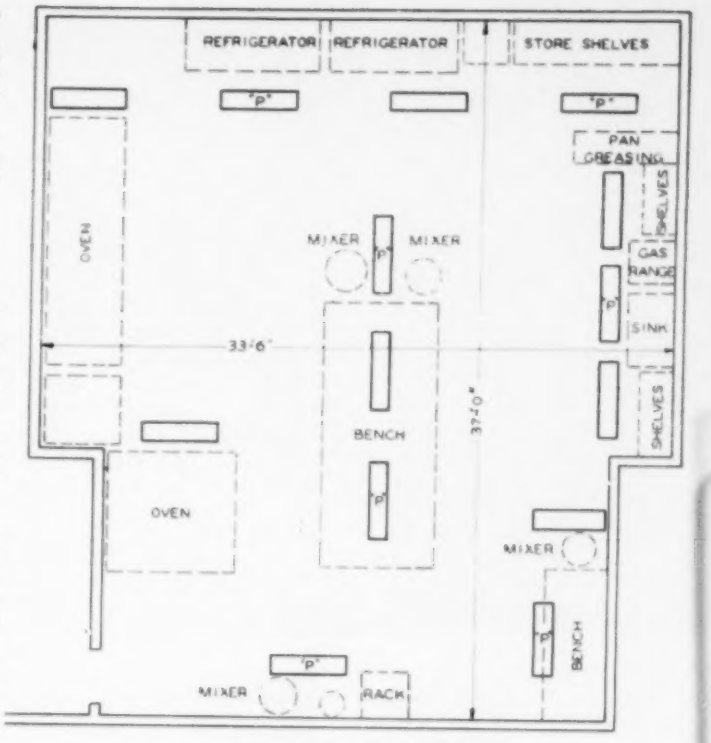


Figure 2. Plan view of typical small bakery.

Figure 3. Typical luminaires suitable for bakeries.

Dome (Filament Lamp)
Vapor Tight with Heat Resisting Glass (Filament Lamps)
Aluminum (Diffused Alzak)
Glassteel Diffuser
Projector Spot or Floodlamp
Glass
Silvered Lamp Diffuser
Fluorescent Industrial Reflector
Vapor Tight with Heat Resisting Glass (Fluorescent Lamps)
Fluorescent Industrial Reflector with Louvers (or Shielding Translucent Cover)

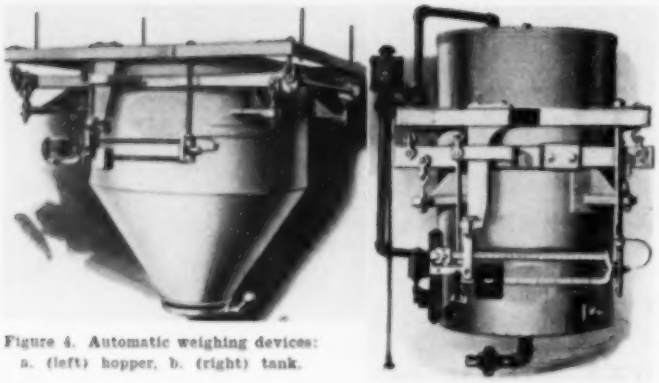


Figure 4. Automatic weighing devices: a. (left) hopper, b. (right) tank.

sign (window efficiency, maintenance factors, reflection factors, etc.) should be considered in the design of daylighting. In general, the chief difference between the methods of designing for daylighting and for artificial lighting is that the amount of daylighting and the direction of light varies.

(c) Openings in walls and ceiling afford a means of obtaining only a portion of the available outdoor light within a room. The portion of the light entering depends upon the size, position, and light transmission of the medium in the opening. Since the upper part of the window is most effective in lighting the far side of the room, the window head should be as high as possible. The amount of daylight from the lower part of the window has little effect on the daylight distribution in the room, so the sill location is arbitrary. In order to reduce excessive brightness ratios, the windows should be provided with some means of light control such as light-controlling glass, light-directional glass block, fixed horizontal and vertical projections, louvers, baffles, venetian blinds, shades, or diffusing screens.

(d) Where the room design is limited to locating windows in one wall it should be as continuous as possible with a minimum of piers and mullions. For deep rooms consideration should be given to the admission of daylight through more than one wall. Sawtooth skylights and monitors mounted overhead are effective methods of utilizing daylighting for single story buildings.

(e) Equipment should be so located that workers never perform their tasks facing a window.

(f) For design data see "I.E.S. Recommended Practice of Daylighting."

5. Lighting for Specific Areas

5.1—*Mixing Room* — **(a)** Flour is normally stored in bins directly above the mixers so that it can be weighed and sifted directly into the mixing bowl. Sometimes it is conveyed to scale hoppers located above the mixers. Standard dial or beam scales are used to weigh the flour and meters to measure the liquid ingredients. See Section 5.8 for the technique of lighting scales and other instruments.

(b) Some mixing rooms have a side bench where additional ingredients are mixed and weighed. General illumination of 20 footcandles with a vertical illumination of 10 footcandles on the face of the shelves is required in this area. For vertical mixers supplementary lighting should be provided to produce 50 footcandles inside the mixing bowl. See Figs. 5, 6 and 7.

5.2—*Fermentation Room* — From the mixing room bread dough is taken in large troughs (holding 1200-1500 pounds) to the fermentation room which is maintained at about 80F and 80 per cent humidity. Here the yeast acts on the sugar; the dough remains in this room until it has risen sufficiently to be divided and panned. Since little attention is paid to the dough during fermentation only sufficient light is required to insure safe handling of the equipment. Due to the high humidity vapor-proof or

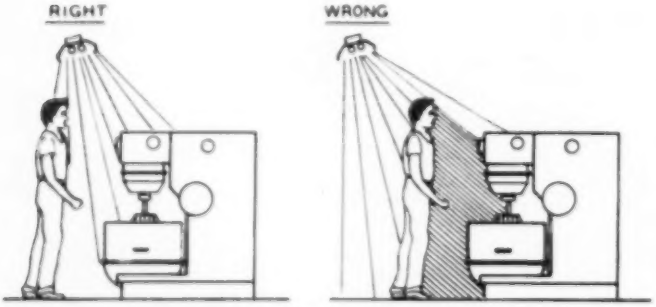


Figure 5. Lighting a single mixing unit.

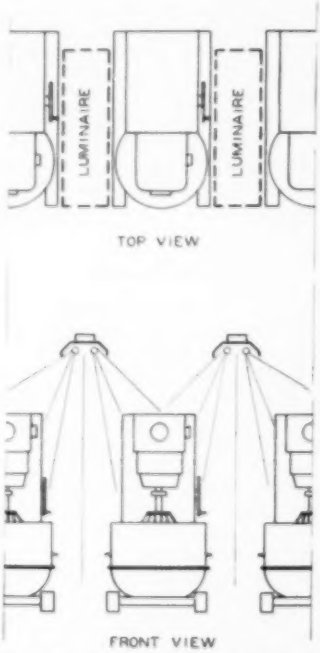


Figure 6. Lighting for several mixing units.

Figure 7. (above) Unloaded from the mixer into a trough, dough is taken next to the fermentation room.

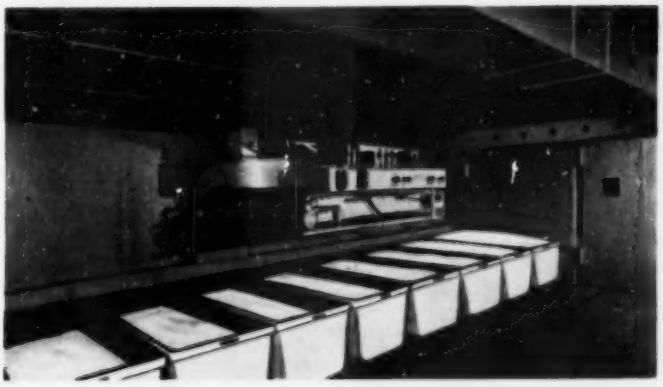


Figure 8. (center) Long troughs of bread dough in fermentation room. Those toward the background which have been in the room longer show greater fermentation than those at the front.

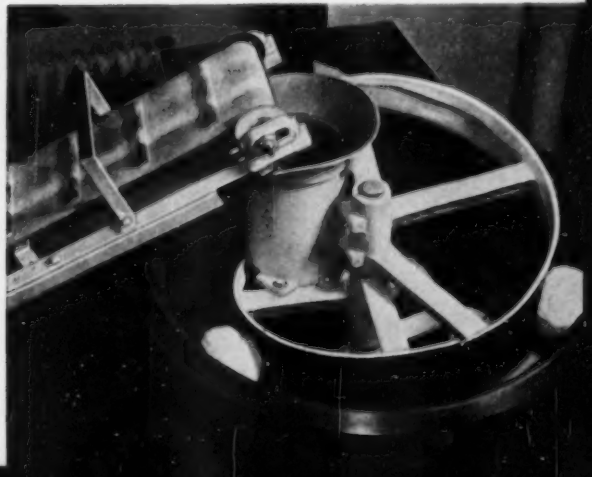


Figure 9. a. Divider and b. rounder for bread.

Figure 10. Doughnut cutting.

vapor-resistant luminaires may be used to advantage in this area, especially for fluorescent lamps. Experiments have shown that ultraviolet radiation can be used to advantage in the fermentation room to control wild molds. See Appendix.

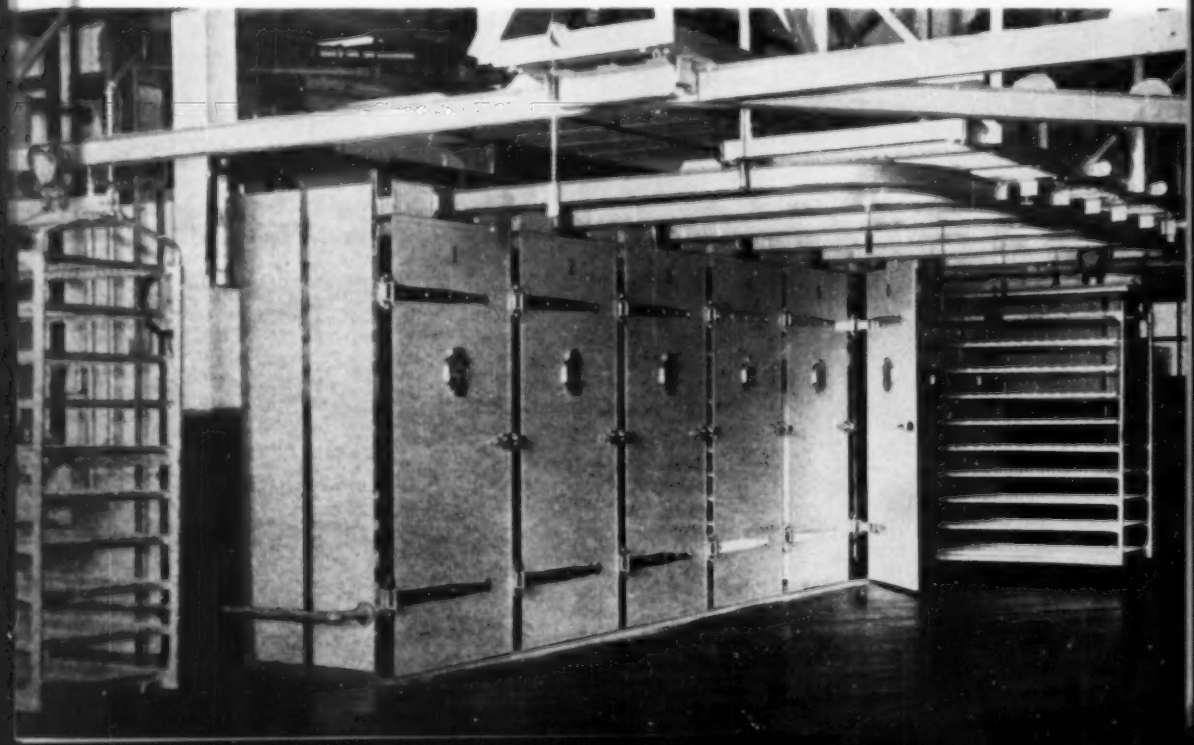
5.3—*Make-up Room* — **(a)** In the make-up room the dough is divided, shaped, and panned preparatory to baking. In modern bakeries production line procedures are used, and the operations are largely mechanical, requiring very little handling. General illumination of 20 footcandles is good practice.

(b) At benches where baked goods are made up by hand 20 footcandles is also adequate. However, where sweet yeast raised goods and other complicated products are made the illumination should be at least 30 footcandles.

5.4—*Proofing Room*—During proofing the panned dough rises, again under controlled temperature and humidity, to acquire its final shape. Localized general illumination is required in the proofing room directly in front of the tray racks so that a quick inspection of the panned dough can be made. Due to the low ceiling of most proofing rooms symmetrical, elliptical angle reflector units, or units with similar sidewise distribution can be used to advantage, the units facing away from the door. See Figs. 11 and 12. Due to high humidity in the proofing room vapor-proof luminaires are suggested, especially for fluorescent lamps.

5.5—*Oven Room* — Ovens present a special lighting problem because many have black and white exterior finishes, and great brightness contrasts may result with the enclosed bare lamp units employed for lighting the interior. The fronts of the ovens should be illuminated so as to balance the brightnesses

Figure 11. A final rise takes place in these proof cabinets before the shaped dough proceeds to the ovens.



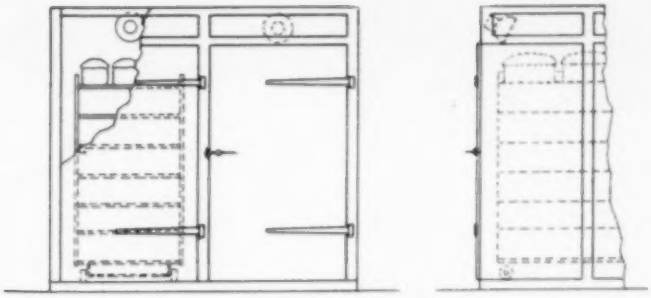
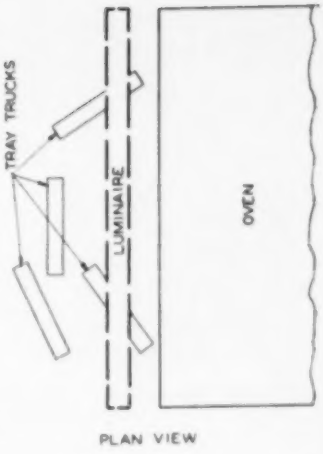


Figure 12. Lighting a proof box.



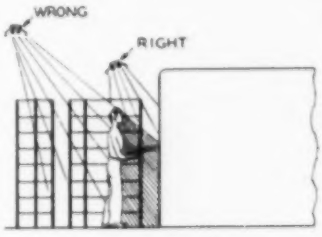


Figure 14. Lighting for ovens.

of the lighted oven opening to keep the brightness ratios within a reasonable limit, not over 10 to 1, and preferably lower. Luminaires must be mounted so that tray trucks placed near the oven mouth when the oven is being filled or emptied do not cause shadows. See Figs. 13 and 14.

5.6—*Fillings and Other Ingredients*—(a) Preparation of fillings involves weighing and mixing various ingredients. Accuracy is required to maintain the proper standards of quality of product. Many of these ingredients are of a perishable nature and must be carefully inspected before use. For these reasons a minimum illumination of 30 footcandles is required with at least 50 per cent vertical component. Luminaires should be placed to provide good illumination for cleaning the inside of the mixing bowl.

(b) For cooking fruit fillings, an exhaust canopy and fan are usually provided above the kettles. Auxiliary luminaires can be mounted inside the canopy, which provides good shielding and properly directs the light. See Fig. 17. Vapor-proof units may be used to advantage to prevent corrosion and to protect the lamp bulbs against breakage from liquid splashing.

(c) Tables for fruit washing, cutting and mixing are normally placed near the windows. Care should be taken that the workers do not face the windows, unless provision is made for the control of excessive glare by means of venetian blinds, shades, etc.

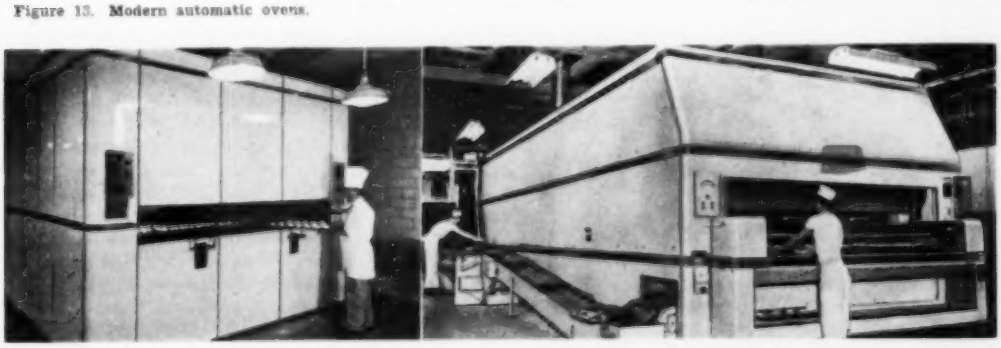
5.7—*Decorating and Icing*—(a) In many large operations, icing is applied to bakery products mechanically. The lighting problem in this case is similar to that in the make-up room, and the solution is the same.

(b) Hand decorating and icing, however, require greater skill and care on the part of the operator if uniformly good results are to be obtained. Because of the detail involved in hand decorating and the necessity of working rapidly if satisfactory rates of production are to be maintained, quick and accurate seeing is required. For this reason it is recommended that not less than 50 footcandles be provided on the decorating benches. Industrial type lighting units are suggested. Low brightness fluorescent lamps have an advantage since they radiate less heat and result in lower brightness reflected from the glossy icings toward the decorator.

(c) If the operators are stationed in only one side of the decorating benches the units may be placed above the heads of the operators parallel to the benches. See Fig. 15. This location is recommended because:

(1) Illumination of the vertical surfaces

Figure 13. Modern automatic ovens.



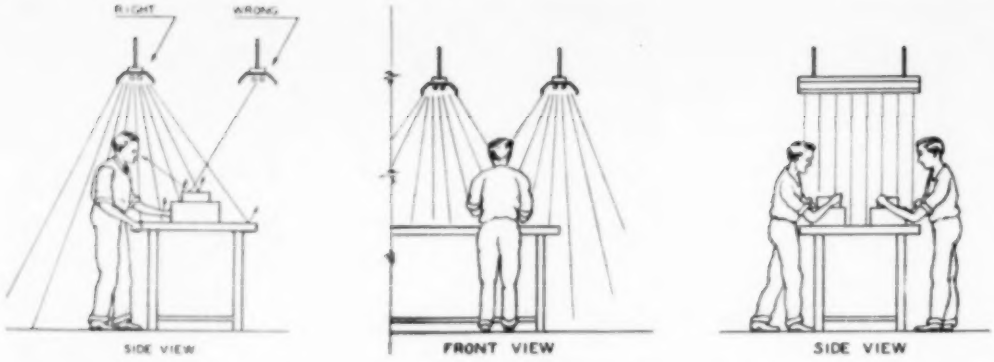


Figure 15. (left) Lighting an icing and decorating table (workers located on one side only). Figure 16 (right) Lighting an icing and decorating table (workers located on both sides of table).

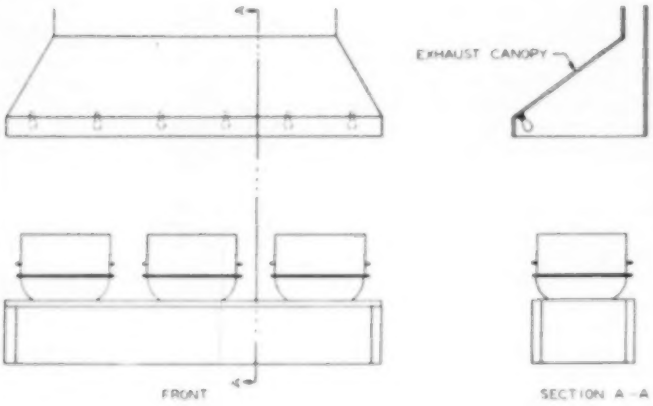


Figure 17. Recommended for illuminating kettles used for cooking fruit fillings are 100-watt inside-frosted filament lamps installed on 20-inch centers in the exhaust canopy.

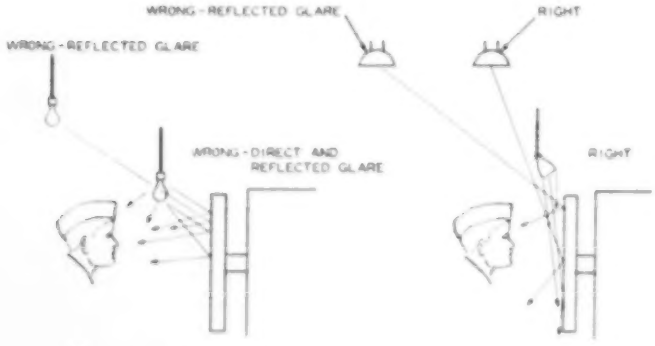


Figure 18. Lighting for meter and scale dials.

of the product will be improved and the slight shadows produced will bring out the detail of the decoration.

(2) Reflections from the highly reflective surfaces of the icing will be directed away from the operator.

The lighting units may be tilted slightly toward the decorating benches if the arrangement of the benches is such that a particular lighting unit is not expected to light more than one bench.

(d) If the operators are located on both sides of the benches, the lighting units should be placed across the benches between the positions of the operators. See Fig. 16.

(e) The color of the light from the units in the decorating and icing department should be as nearly as possible the same as that under which the product will be purchased and consumed. Since in homes and restaurants filament lighting is as likely to be found as fluorescent, it is recommended that either filament or fluorescent lamps which approach the color of filament sources be used to illuminate the decorating benches.

5.8—*Illumination of Scales and Thermometers* — For quick accurate reading of the graduations, these instruments should be illuminated to provide a brightness of from 20 to 25 footlamberts. However, special care must be taken to prevent direct or reflected glare from the scale due to luminaires or windows. See Figs. 18 and 19. An illumination level of about 30 footcandles is adequate to produce the above brightness for most gauges, thermometers, and scales. Easier maintenance usually results if the

lighting equipment is removable. Where a local light source cannot be used suitable shielded spotlights are recommended.

5.9—*Wrapping Room*— (a) Wrapping is done on automatic machines, and there may be frequent interruptions caused by torn wrappers, clogging of the mechanism, etc. Diffused general lighting is required to expedite location and removal of obstructions and cleaning, oiling, and adjustment of the machines. See Fig. 20.

(b) To control mold in packaged bakery goods bactericidal lamps can be used to advantage. For detailed information see Appendix.

5.10—*Storage*—(a) Proper illumination of the storage room is important. Adequate illumination promotes good housekeeping and thus tends to decrease storage losses.

(b) Since low ceilings are frequently found in storage rooms, special attention must be paid to proper shielding of the lamps. See Fig. 21. Industrial filament or fluorescent units of any type shown in Fig. 3 can be used. Correct placing of the units with regard to the bins, platforms, etc., is essential to prevent blocking of light from the working areas.

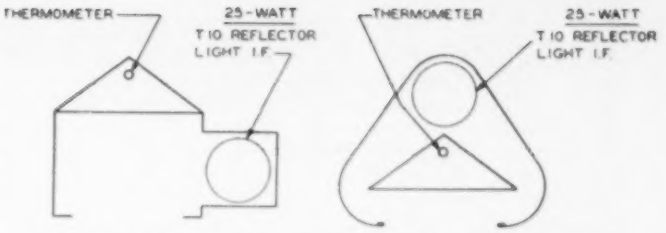


Figure 19. Two suggested methods for illuminating thermometers.

TABLE II.—Filament Lamp Equipment.

Indication of Trouble	Cause and Remedy
1. Lamp not burning but apparently O.K.	Lamp loose — (a) Tighten in socket Loose or broken connections — (a) Secure terminals (b) Repair wiring
2. Lamp burns dim.	Low voltage — (a) Match lamp rating to line voltage (b) Increase line voltage
3. Short lamp life.	High voltage — (a) Match lamp rating to line voltage (b) Improve voltage regulation and avoid surges Bulb cracked due to mechanical shock — (a) Replace lamp (b) Be sure water does not drip on bulb Incorrect lamp — (a) Replace with lamp of size for which luminaire is rated Excessive vibration — (a) Use shock absorbing device
4. Lamp breakage.	Water contacts lamp bulb — (a) Use enclosed, vaportight luminaire if water spray is present (b) Seal joint where conduit stem enters luminaire Bulb touches luminaire — (a) Use correct size of lamp (b) Straighten socket

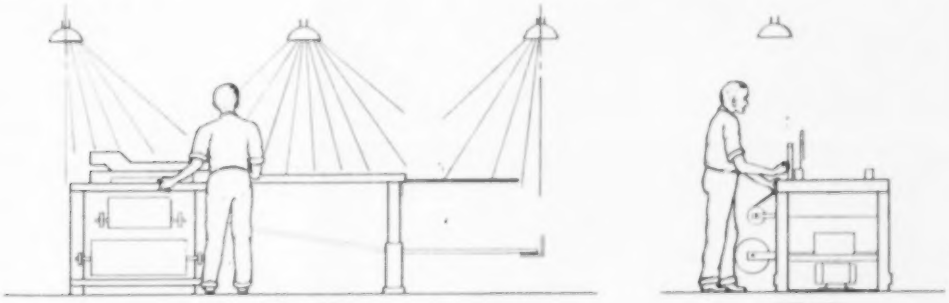
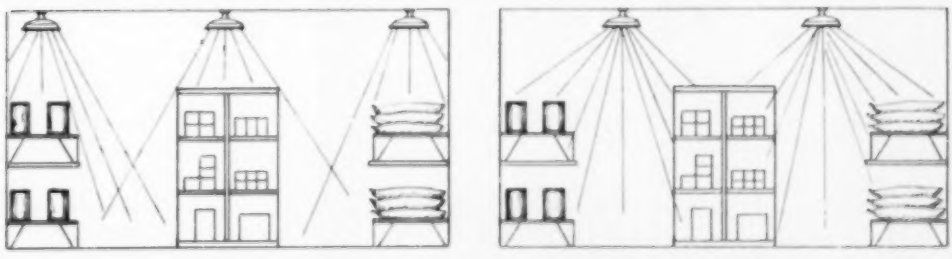


Figure 20. (above) Lighting for wrapping machines. Figure 21. (below) Lighting of storage areas.



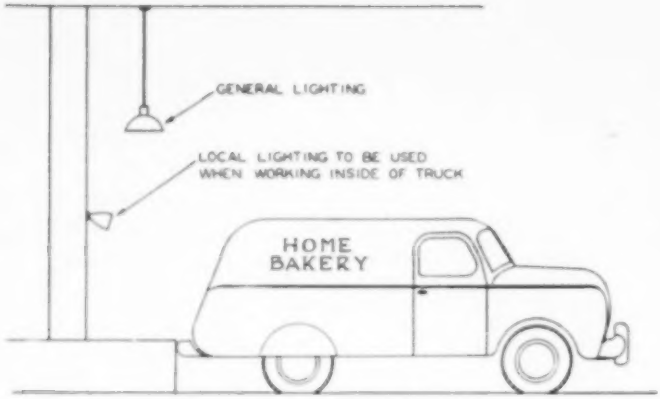


Figure 22. Lighting a loading platform.

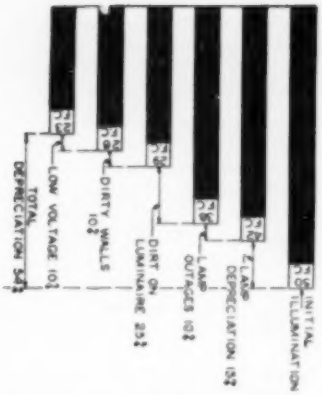


Figure 23. Depreciation factors for a typical lighting system.

Figure 24. Recommended cleaning procedure: (1) take down lamps and reflector, (2) wash reflector thoroughly, and (3) wash lamps thoroughly.

5.11—*Shipping Room* **(a)** The finished product is delivered to the shipping room by tray trucks or conveyors. Shipping room tasks include keeping shipping records, loading delivery trucks, and in some places maintenance and cleaning of the delivery trucks. The loading platform should have a minimum level of illumination of 20 footcandles. This level is required because clerical work such as checking is done at this point as well as inspection of the product for damages in handling etc. This general lighting of the loading platform can be obtained by means of industrial filament or fluorescent units.

(b) Since the delivery truck bodies are enclosed and are loaded from the rear door, it becomes necessary to use angle or projector equipment permanently attached to wall, column or other facilities appropriately located to provide adequate seeing conditions within the truck body. See Fig. 22.

(c) Although the lighting of the garage proper is considered to be a separate study, it is desired to emphasize the necessity of providing sufficient light to insure proper cleaning of the trucks.

5.12—*Offices and Other Locations* —The lighting in the office area should follow the recommendations given in "Recommended Practice of Office Lighting" prepared by the Office Light-

ing Committee of the Illuminating Engineering Society.

6. Maintenance

6.1—*Artificial Lighting*—(a) Fig. 23 indicates the depreciation factors which contribute to the effectiveness or ineffectiveness of any lighting plan. About 10 to 15 per cent of the total depreciation of 54 per cent shown is due to normal reduction of lumen output throughout the life of the light source. The remainder can be reduced by a scheduled maintenance program including frequent cleaning of all reflecting and light transmitting surfaces and inspection of the surroundings and electrical system. See Fig. 24.

(b) Such devices as fluorescent lamp and starter testing apparatus are useful to a maintenance department. Check charts for fluorescent, mercury, or filament lamp equipment frequently prove to be time savers. Table II is an example of such information covering filament lamp equipment.

(c) The following basic rules are a guide to obtaining efficient and economical lighting:

(1) Maintain proper line voltages.

(2) Replace lamp outages promptly.

(3) Clean luminaires regularly.

(4) Become familiar with luminaire circuits, lamp and starter testing methods.

6.2—*Daylighting*—Definite maintenance schedules should be established also for cleaning windows and related light controlling media. The rate of light loss depends upon dirt accumulation, which in turn is dependent upon the building location, atmospheric conditions, etc. In general, the windows and other light controlling media should be cleaned at least twice a year.

Appendix
Ultraviolet Radiation to Control Mold Contamination

This appendix is not part of the report. Although the Illuminating Engineering Society is concerned with the generation, distribution and measurement of radiation beyond the visual spectrum it does not include within its scope the subject of the effects of such radiations. The intensities of radiation produced by ultraviolet lamps used as suggested in this appendix represent opinions of individual authorities and not of the Illuminating Engineering Society.

(a) Growth of mold on bakery products is caused by spores floating in the air. Spores, produced by molds growing in out of the way places in the bakery or brought in by the incoming air from outside, settle on any surface in the bakery and under favorable conditions of moisture and heat produce mould.

(b) Laboratory investigations as well as field tests have shown that low intensities of ultraviolet radiation inhibit the growth of mold on surfaces favorable to growth. The tests have shown, too, that higher intensities of radiation will kill spores floating in the air. The basic method of mold control is the prevention of mold growth on machinery, walls, and ceiling and sterilization of air.

(c) The fermentation room is one location in the bakery most apt to produce a problem because of mold growth on the walls and ceiling. To inhibit growth of mold in these locations bactericidal lamps should be installed to provide the necessary intensity of radiation. There are two methods of application of ultraviolet radiation in a bakery, direct and indirect. When using the direct method, the bactericidal units are located directly on the ceiling or suspended therefrom in order to irradiate the whole room. In this case, 15-watt lamps are used, one lamp for each 50-60 square feet of floor area. Where workers are exposed to the ultraviolet radiation for prolonged periods of time, eye shields should be used to prevent over-exposure. The indirect method is based on irradiation of the upper part of the room by indirect fixtures. One 30-watt lamp is used per 75-100 square feet of floor area. The indirect fixtures should be hung as low as possible so as to irradiate the walls and surfaces above the eye level. The usual mounting height is about 7 feet.

(d) During the summer months mold frequently develops in packaged bakery foods, such as bread, rolls, cakes, etc. Since the product is free of viable mold spores when it leaves the oven, the contamination must occur during the cooling and wrapping processes. Ultraviolet irradiation has been used by other food industries to control growth of micro-organisms in confined spaces and therefore it appears possible that ultraviolet may have some practical application in cooling rooms or cooling tunnels to prevent contamination of bakery products with air-borne mold spores. Bactericidal lamps can be placed in the intake duct to sterilize the incoming air and may be placed in cooling tunnels to maintain sterility of the equipment and of the air used to cool the bread. The number of lamps used for this purpose would depend upon the size of the duct or tunnel, their proportions, the interior surface of the duct or tunnels and the humidity of the air used and the volume of air being circulated. The following data serve as an example of the requirements that might be needed for the cooling of bread: In a duct 20 by 40 inches with an interior surface providing 60 per cent reflectance of ultraviolet light, through which 6000 cubic feet of humid air is pulled each minute, thirteen 30-watt bactericidal lamps are required to effect a 99 per cent mold kill.

(e) It would be necessary to experiment with each type of cooling tunnel to assure proper placement of the bactericidal lamps for the prevention of mold growth on surfaces of the equipment and to provide a substantial kill of airborne mold spores within the tunnel.

(f) Provided means have been taken to assure against the contamination of the finished bakery product by mold during the cooling process, bactericidal lamps placed near and inside the wrapping machine would assure against the growth of mould in crevices of the machine and would provide sterile air around the bakery product during the wrapping process. Such use of bactericidal lamps on the wrapping equipment will not kill mold which has already gained access to the product because the exposure time is too short and the irregularities of the surface of the baked food makes it impossible for the ultraviolet irradiation to reach all of the contamination.

(g) It is very important that all bactericidal lamps be placed in such a position that no direct radiation can reach the worker's eyes. Where this is impossible the workers' eyes should be protected by suitable goggles or eye shades. Where prolonged occupancy is anticipated, the walls and ceilings of rooms where bactericidal lamps are used should be finished with low ultraviolet reflectance paints, or other wall coverings, to reduce the radiation value at the eye level and to protect the exposed parts of the workers' skin.

Reprints Available

Reprints of the report "Lighting for Bakeries," in pamphlet form, with cover, will be available at 50 cents for single copies. Quantity rates on application to the Publications Office, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Preview of Program, 1950 Southern California National Technical Conference

As President Goddard said on a recent preview of Conference facilities at the Hotel Huntington, Pasadena, California, "Beg, borrow, or steal the time to get to the Pasadena Conference." You will be thrilled by the park-like grounds, the turquoise pool, sports facilities, comfortable resort-type restful atmosphere, and adequate meeting space of the hotel. In addition to this grand hotel, Pasadena and Los Angeles County, with its countless attractions to the visitor, will make this year's conference be one you cannot afford to miss. Beg the time; steal the money!

The opening of the Conference will be at 11:00 o'clock, Monday morning, August 21, with the first of the technical sessions scheduled to start at 2:00 p.m., Monday, August 21.

An outstanding technical program for the Southern California National Technical Conference has been prepared by the Papers Committee, and the National Technical Conference Committee. Conference papers to be presented at Pasadena, as presently scheduled, but subject to change, are:

First General Technical Session
Monday, August 21

Evaluation and Comparison of Modern Office Lighting Systems, by George J. Taylor, Day Brite Lighting Inc., St. Louis, Mo.

Lighting in Agriculture, by J. P. Ditchman, General Electric Co., Nela Park, Cleveland, Ohio.

A.C. Fluorescent Lighting of Subway Trains, by E. W. Beggs, Westinghouse Electric Corp., Bloomfield, N. J.

A Specification for Color Rendering Properties of Fluorescent Lamps, by Chas. Jerome, Sylvania, Salem, Mass., and Dr. D. B. Judd, National Bureau of Standards, Washington, D. C.

Illumination for Sight Testing, by Dr. Henry Hofstetter, Los Angeles College of Optometry.

Technical Session on Sources

Glow Switch Transients for Starting Fluorescent Lamps, by F. H. Ruxton, Westinghouse Electric Corp., Bloomfield, N. J.

Reflector Contours for Pressed Glass Lamps, by P. F. Dietz, Westinghouse Electric Corp., Bloomfield, N. J.

New Glass Developments in the Field of Illumination, by Dr. W. Shaver, Corning Glass Works, Corning, N. Y.

The Development of High Wattage Tungsten Lamps Particularly for Infra-Red Applications, by R. G. Slauer, Sylvania Electric Products Inc., Salem, Mass.

Bulb Sizes — Incandescent Filament Lamps, by W. E. Anderson, Westinghouse Electric Corp., Bloomfield, N. J.

Electrodes in Thermionic Fluorescent Discharges and Their Importance to Lamp Performance, by Dr. E. F. Lowry, Sylvania Electric Products, Danvers, Mass.

New Photochemical Lamps, by L. E. Barnes, Westinghouse Electric Corp., Bloomfield, N. J.

Lighting Service Forum—8:00-10:30 p.m.

Residence Lighting Technical Session
Tuesday, August 22

Lighting for the Home Sewing Machine, by Myrtle Fahsbender and Priscilla Presbrey, Westinghouse Electric Corp., Bloomfield, N. J.

Lighting Fixture Design for Homes of Today and Tomorrow, by N. H. Vacha, John Virden Co., Cleveland, Ohio.

Fluorescent Lighting in the Home, by Kaye Leighton and E. W. Commery, General Electric Co., Nela Park, Cleveland, Ohio.

Residence Lighting Forum — What It Is and What It Does, by Priscilla Presbrey, Chairman — Residence Lighting Forum Committee.

Street Lighting Technical Session (Parallel)
Effective Practice in Lighting Unusually Hazardous and Irregular Roadway Areas, by R. M. Sweitland, General Electric Co., West Lynn, Mass.

Lighting of the Battery Brooklyn Tunnel, by L. G. Goenens, Triborough Bridge and Tunnel Authority and Kirk Reid, General Electric Co., Cleveland, Ohio.

Temperature Problems in Street Lighting Luminaires, by R. W. Loehr, Westinghouse Electric Corp., Cleveland, Ohio.

Studies of Discomfort Glare in Street Lighting, by Professor R. C. Putnam and R. Fawcett, Case Institute, Cleveland, Ohio.

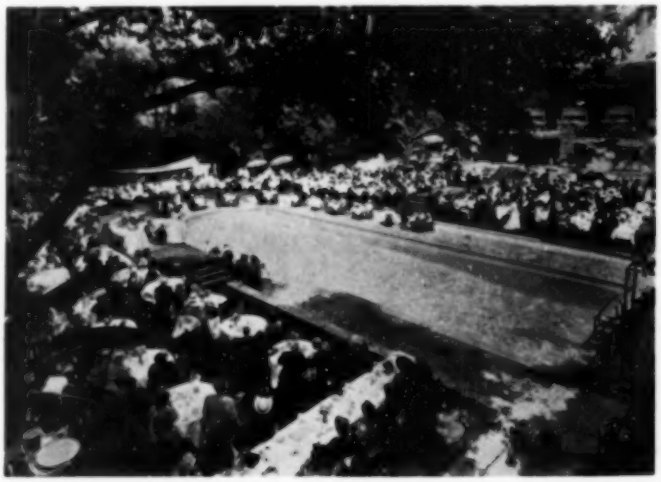
Lighting of the Mystic Bridge, by Walter Mc Clain, J. E. Greiner Co., Baltimore 2, Md.

Second General Technical Session
Functional Lighting in Canadian Church Building, by H. C. Jones, Canadian General Electric Co., Toronto, Canada.

A Method of Testing and Evaluating Fluorescent Luminaires, by Kurt Franck, Holophane Company Inc., Newark, Ohio.

Studies in Lighting of School Auditoriums and Stages, by C. J. Allen, General Electric Co., Nela Park.

The Effect of Task Brightness to Surround Brightness Ratios on Visual Performance (Research Fund Project), by Professor R. L. Biesele, Jr., Southern Methodist University, Dallas, Texas.



THE MAGNIFICENT Turquoise Pool at the Huntington Hotel, Pasadena, will allow you to relax and enjoy the moments before and after the technical sessions. Surrounded by spacious gardens and the celebrated picture bridge, this spot will be a popular one.

TO MAKE the 1950 Southern California Conference "The Conference That Will Have Everything," many men are hard at work. Some of the local and national Conference planners are (left to right) D. W. Prideaux, Chairman of the Conference Executive Committee; R. F. Hartenstein, Chairman of the National Technical Conference Committee; C. H. Goddard, President of I.E.S.; Walter Sturrock, Vice-President; and Hoyt P. Steele, Chairman of the Papers Committee.

Muscle Action Potentials as Related to Visual Tasks in Industry, by Willard Allphin, Sylvania Electric Products, Danvers, Mass.

Informal Social Party—Ball Room—8 p.m.

Technical Committee Forum

Wednesday, August 23

Planned Recreation in the Afternoon

Progress Report—Ball Room—10 p.m.

Aviation Lighting Technical Session

Thursday, August 24

Lighting for Safe Flying, by D. W. Rentzel, Civil Aeronautics, Washington, D. C.

Aircraft Lighting and Lighting Developments, by W. C. Bryant, Lockheed Aircraft Corp., Burbank, Calif.

Summation of Approach Light Testing at Landing Aids Experiment Station, Arcata, Calif., by H. J. Cory Pearson, Civil Aeronautics Administration, Indianapolis, Ind.

Advances in Airport Lighting, by W. A. Pennow, Westinghouse Electric Corp., Cleveland, Ohio.

Third General Technical Session

Daylight in Classrooms Multilateral Lighting, by Professor R. L. Biesele, Jr., Southern Methodist University.

Comfortable Brightness Relationships for Critical and Casual Seeing, by S. K. Guth, General Electric Co., Nela Park, Cleveland, Ohio.

An evaluation of the Performance of Fluorescent Fixtures, Lamps and Ballasts, by Benjamin S. Benson, Jr. and Eric H. Church, Benjamin Electric Mfg. Co., Des Plaines, Ill.

Visibility Test Methods (Research Fund Project), by Dr. C. L. Cottrell, Cornell University, Ithaca, N. Y.

A Fundamental Process for Producing Light, by Eric Mager and Dr. E. Paine, Sylvania Electric Products, Inc., Salem, Mass.

Experience Studies of Louverall Ceilings in Department Stores, by D. P. Caverly and R. Wylie, Sylvania Electric Products, Inc., New York, N. Y.

President's Reception and Banquet—6:30 p.m.

The traditional President's Reception, Banquet, and Ball, will take on added interest this year as all activities will center around the beautiful, well-lighted Huntington pool and surrounding gardens. True California outdoor living at its best. Come meet the President, see your friends, enjoy a full evening of conviviality, dining and dancing under the stars—comfortably. There is virtually no rain from June to September in Southern California; the weather is warm in the sun, cool in the shade, and cool and pleasant in the evenings.

Ladies' Program

The Ladies' Reception Committee has some tremendous plans to keep the ladies busily engaged enjoying their stay to the fullest. The ladies' program consists of:

Monday Afternoon, August 21: A leisurely tour of Pasadena and nearby communities to see such world-famous spots as the Huntington Library, Art Gallery, and Botanical Gardens, Mission San Gabriel, famous homes, the Rose Bowl, etc.

Tuesday, August 22: Tour to Olvera Street (Mexican shops), Snyder home, *The* Farmers' Market (for lunch), Hollywood Bowl, the Greek Theatre, tea at Olive Hill Foundation (Frank Lloyd Wright design), returning in time for rest and dinner at the Huntington Hotel.

Wednesday Afternoon, August 23: A joint tour with the men (of special interest).

Thursday, August 24: A delightful drive along Los Angeles' Miracle Mile on Wilshire Boulevard, to Santa Monica and the blue Pacific Ocean; then past some of the fabulous homes of Bel-Air, to Stone Canyon, a tropical park in the hills above Beverly Hills, for a delightful luncheon, cooked electrically, and a period of pleasant entertainment. Returning will be a leisurely tour through Hollywood, back over the Arroyo Seco Parkway.

Sports Program

The sports facilities at the Huntington Hotel are superb. In a secluded but spacious garden setting, the large and beautiful turquoise pool invites young and old alike to a refreshing plunge. Four glare-proof surfaced tennis courts beckon the most discriminating player or the novice. A fine surfaced badminton court near the pool and a nine-hole golf putting course complete the sports facilities at the hotel proper. Riding stables are available close by for the equestrian-minded. All sports facilities at the Huntington will be available to all I.E.S. registrants, whether they are staying at that hotel or not.

Provision will be made for interested golfers to compete for the President Law cup at one of the several courses nearby.

Lighting Service Forum

John Walsh and his utility committeemen are planning a unique and colorful "show type" of Forum this year. You can always expect the unusual and interesting from this group—you won't be disappointed this year.

Transportation

A colorful Grand Canyon I.E.S. Special is planned, starting from Chicago on August 18th, with additional cars being added at Kansas City; Wichita, Kansas; Amarillo, Texas; and Belen, New Mexico. Groups from other parts of the East can attach their special cars to the I.E.S. Special, and enjoy the trip with I.E.S. friends, stop over one day at the Grand Canyon, then on to Pasadena, arriving Monday morning, August 21st.

Circle return trips are suggested for all I.E.S. members attending so that full realization of time and expenditures may be made. Trips from east of the Mississippi can be routed via

Los Angeles to San Francisco, Portland and Seattle at no extra rail fare, and for only a few pennies more, Canada can be included. A trip to the West Coast will not be complete unless these famous western cities, with their many attractions are visited, along with the great national parks and tremendous dams and power projects which are predominantly in the West. Places like the Black Hills of South Dakota, Spokane, Washington, the Great Salt Lake, Reno and Las Vegas, Nevada. Why not route your trip to include as many as your time will allow?

Many members will fly to take advantage of the time saved. Air coach by TWA and American, and week-day half-fare rates for families will appeal to many. Then, too, many I.E.S. members will bring their families and friends by auto. Motels in the West are grand, comfortable—some even lavish—and economical. Auto travel information is available from the Auto Club of Southern California, 2601 So. Figueroa St., Los Angeles.

The timing of this year's conference in Southern California allows the I.E.S. member and his family to take a vacation in conjunction with a trip to the conference, and be home in adequate time for reopening of school.

"Lighting for Tomorrow" Keynote of Pacific Northwest Regional Conference

Regional Conferences "tread upon one another's heels, so fast do they follow" in the Spring. An outstanding one leading the way in the West was the two-day conference in Seattle, March 23-24, conducted by Sections and Chapters of the Pacific Northwest Region.

In setting up their program, the Conference planners initiated a form of presentation which proved so popular it may become standard for future meetings. The sessions were so arranged that the first day's program consisted entirely of general sessions, all held in the main ballroom of the Meany Hotel. The speakers here presented talks of general interest, to be followed next day with more complete discussions in special panel sessions. The second day's meeting featured the panel discussions in three rooms, enabling in this way, eleven discussion periods of one and a half hours each. Conference planners were encouraged to note that these rooms were filled to capacity for each discussion, and as the discussion leader gave only a short talk outlining the subject, most of the time was devoted to a valuable exchange of viewpoints.

A field trip tour of the University of Washington, part of the Conference program, was especially successful. About 60 of the Conference delegates made this tour. Lyman Morgan, who designed the lighting in several new U. of W. buildings helped conduct the tour. Incandescent lighting predominates in these new buildings, a feature which stimulated further valuable discussion during the inspection.

A banquet and dance on Friday, March 24, with I.E.S. President and Mrs. Goddard guests of honor, concluded the Conference.

President Goddard, in his address, made reference to I.E.S. Standards in use today, particularly in the northwest area. He noted, for instance, that the State of Washington has adopted as safety standards the I.E.S. recommendations for industrial lighting, and that the schools are required to be lighted in accordance with the I.E.S. recommendations for school lighting.

An officers' breakfast with President Goddard was held the following Saturday morning, not part of the Conference, but of special value to the Boards of the Sections and Chapters comprising the Pacific Northwest Region. Mr. Goddard reported on current I.E.S. activities and participated in a discussion of various local problems brought up by the officers. At this breakfast, it was decided that the next Pacific Northwest Regional Conference would be held in Spokane, Washington in the spring of 1951, the Inland Empire Chapter being host.

Technical Sessions

Mayor of Seattle, William F. Devin opened the meeting with an Address of Welcome, to which President C. H. Goddard responded on behalf of the Society. The keynote address "Lighting for Tomorrow" was made by B. T. Heinz, Co-Chairman of the Conference Committee. For the record, the program included:

Thursday, March 23, 1950
Main Ball Room
Edmond Meany Hotel

Morning Session—Chairman, Eric E. Ackland

Opening Address—Eric E. Ackland, Vice President, Pacific Northwest Region, I.E.S.
Address of Welcome—Mayor Wm. F. Devin, City of Seattle.
Response—Charles A. Goddard, President, Illuminating Engineering Society.
Keynote Address—"Lighting for Tomorrow," by B. T. Heinz, Co-Chairman Conference Committee.
Technical Presentation—"Color and Light Sources," by Robert V. Bardsley, Sylvania Electric Products, Inc.

AT THE successful Pacific Northwest Regional Conference, Seattle, Washington, Paul Marble (right) Puget Sound Section, presents totem pole to Pres. Goddard.

HEAD TABLE at the banquet, Pacific Northwest Regional Conference, Seattle, Wash., March 24. Left to right, Mr. and Mrs. K. E. Hollingsworth, Mr. and Mrs. B. A. Travis, J. D. Webster, Mrs. Ackland, Eric Ackland, Mrs. Goddard, Pres. Goddard, Mr. and Mrs. Henry Huber, Mr. and Mrs. F. D. Bolton, C. A. Scheyer, Mrs. Heinz and B. T. Heinz.

Afternoon Session—Chairman, Henry R. Huber

"Store Lighting" by C. M. Cutler, Nela Park, General Electric Company.

"Lighting in Architecture," by Walde B. Christenson, President, A.I.A., Seattle Chapter.

"Solving Visibility Problems and Measurements," by A. A. Eastman, Nela Park, General Electric Company.

"Work of I.E.S. Committees," by Robert J. Swackhamer, Chairman I.E.S. Committee on Sports and Recreational Lighting.

Field Trip to University of Washington, Professor Gordon R. Shuck and Byron G. Lind.

Friday, March 24, 1950

Mezzanine, Edmond Meany Hotel

Discussion Panel

F. D. Bolton, Chairman, British Columbia Section

"Luminaire Design," Discussed by A. E. Simpson, Vancouver, B. C., Consulting Engineer.

"Outdoor Flood and Recreation Lighting," Discussor, R. J. Swackhamer, General Electric Co., Lynn, Mass.

"Store Lighting," Discussor, C. M. Cutler, General Electric Co., Nela Park.

"School Lighting," Discussor, Howard Stingle, Public Schools, Spokane, Wash.

C. A. Rost, Chairman, Inland Empire Chapter

"Office Lighting," Discussor, T. W. Finch, Portland General Electric, Portland, Oregon.

"Street Lighting," Discussor, J. W. Arch Bedlong, Traffic Engineer, City of Seattle.

"Residential Lighting," Discussor, Harry C. Lynde, Consulting Engineer, Seattle, Wash.

J. Daniel Webster, Chairman Oregon Section

"Use of Visibility Meter," Discussor, A. A. Eastman, General Electric Co., Nela Park.

"Industrial Lighting," Discussor, Henry R. Huber, Benjamin Electric Co., Seattle, Wash.

"Ultra-violet Applications," Discussor, Fred Cooper, Westinghouse Electric Mfg. Co., Seattle, Wash.

"Airport Lighting," Discussor, Lloyd E. Harrison, C.A.A., Seattle, Wash.

Committee Personnel

The Conference was under the able direction of B. T. Heinz and K. E. Hollingsworth, of the Puget Sound Section, serving as Co-Chairman of the General Conference Committee. Working with them were:

Technical Program	B. A. Travis
Entertainment	C. A. Dickinson
Ladies' Entertainment	Edith Rauch
Field Trips	Byron Lind, G. R. Shuck
Arrangements	P. L. Marble
Registrations	W. H. Creech
Properties	Don King
Publicity	K. E. Hollingsworth, Ted Birchard
Finance	C. A. Scheyer

Officers of the Pacific Northwest Sections and Chapters participating were:

Chairman, Puget Sound Section, Henry R. Huber, Seattle.

Chairman, Oregon Section, J. Daniel Webster, Portland.

Chairman, British Columbia Section, F. D. Bolton, Vancouver, B. C.

Chairman, Inland Empire Chapter, C. A. Rost, Spokane.

Council Executive Meeting Held in Montreal

The national officers, gathered in Montreal for the Canadian Regional Conference, held the regular meeting of the Council Executive Committee there on May 10. Present were: C. H. Goddard, President; S. G. Hibben and Walter Sturrock, Vice-Presidents; E. M. Strong, Treasurer; A. H. Manwaring, General Secretary; G. Ross Henninger, Editor-in-Chief I.E.S. Publications; and C. A. Cathers, G. F. Dean, Duncan M. Jones, Arthur Mendel, G. F. Mudgett, Frank G. Reed, Joseph Thomas, John Ward, and George Watters.

Two Members Emeritus Elected

On the recommendation of the General Board of Examiners, Dr. Matthew Luckiesh, Fellow, and Mr. Henry Maisonneuve (Paris, France), were elected to the grade of Member Emeritus. Details of the distinguished careers leading to this Society honor will be included in the next issue of Telecast.

The balance of the General Board of Examiners report, submitted by E. W. Fahey, Chairman, reported the election of 91 Associate Members, 38 Student Members, and recommended the election by Council of 18 Members. The current membership totals reported, after elections and resignations were:

September 30, 1949		May 10, 1950
6883	Total Membership	7313
26	Members Emeritus	33*
44	Fellows	41
1521	Members	1628
5048	Associate Members	5269
244	Student Members	342

*Includes 8 Fellows of the Society.

New Student Branch at City College, New York

The Society's first eastern Student Branch was approved for charter, on petition submitted by a number of students at the City College of New York. Professor Abraham Abramowitz was appointed as a local representative of the Society and Advisor to the C.C.-N.Y. Student Branch.

Student Activities

In a brief discussion of the activities of Student Members throughout the country, Mr. Hinckley reported considerable activity at the Pacific University, Forest Grove, Oregon, noting the interesting circumstance that many new Student Members there are enrolled with the University's School of Optometry. Mr. Hibben reported an expression of interest in the establishment of an I.E.S. Student Branch, from an Institute of Applied Arts and Sciences.

Section and Chapter Boundaries Established in Canada

Upon presentation by G. F. Dean, Canadian Regional Vice-President, ac-

tion was taken to approve a restatement of boundaries of Sections and Chapters within the Canadian Region. This, in effect, assigns all of the territory in the Canadian Region, from the border to the tundras, and from the borders of the Pacific Northwest Region to Labrador and Newfoundland, to a specific group in the Canadian Region.

Winnipeg Chapter, Canada's Eighth Group, Receives Charter

The official "birth certificate" to a new I.E.S. Chapter has been received by Canada's newest group in Winnipeg, Manitoba. The new Chapter's formal charter was presented at a dinner ceremony held at the Royal Alexandra Hotel in Winnipeg, on April 13. Guest of Honor and main speaker at the meeting was G. Franklin Dean, Canadian Regional Vice-President, who made the presentation to E. F. Wilson, Chairman of the Winnipeg Chapter. Mr. Dean was, in turn, presented with a silver letter opener, with an engraved handle and Winnipeg crest, in appreciation of the efforts which had culminated in the historic Charter meeting.

Another notable presentation was a beautiful gavel of choice Quebec maple, a gift from the Quebec Chapter, next "youngest" I.E.S. Chapter—also a Canadian group. Formal presentation of the gavel was made by Douglas C. Borden of the Quebec Chapter. Mr. Borden dwelt for a moment, in his presentation speech, on the wheat sheaf design carved on the head. It represented, he said, a clasping of the hands from the East and the West, symbolizing the understanding and friendship, not of two different peoples, but of Canadians all. Mr. Borden was the recipient of a pair of miniature cowboy boots, identical in detail to those worn by those lofty Manitobans, presented with the remark that he had been a long time in the saddle (former Chairman of Montreal and otherwise active) and was due a new pair of boots.

Winnipeg is the eighth city in Canada to have an official I.E.S. group—the seventh in the Canadian Region (British Columbia Section in Vancouver is affiliated with the Pacific Northwest Region). In his address to the new group, Mr. Dean reviewed the history of the Society, and expressed the hope that the birth of the Winnipeg Chapter presaged an eventual forming of a Canadian midwest region.

LIGHTING CALENDAR

Society Events

June 8, 1950 — Meeting of I.E.S. National Council, New York, N. Y.

June 9, 1950 — Local Activities Conference for outgoing and incoming local officers of I.E.S., New York, N. Y.

August 21-24, 1950 — Southern California National Technical Conference, Hotel Huntington, Pasadena, Calif.

October 26-27, 1950 — Northeastern Regional Conference, Hotel Statler, New York, N. Y.

Industry Events

June 4-7, 1950 — The American Society of Refrigerating Engineers, 37th Spring Meeting, Muehlebach Hotel, Kansas City, Mo.

June 5-7, 1950 — Edison Electric Institute, 18th Annual Convention, Atlantic City, N. J.

June 12-16, 1950 — American Institute of Electrical Engineers, Summer General Meeting, Pasadena, Calif.

June 12-16, 1950 — National Association of Electrical Distributors, Atlantic City, N. J.

June 12-16, 1950 — Conference on Industrial Research, Columbia University, New York, N. Y.

June 15-19, 1950 — 60th Annual Meeting, Canadian Electrical Association, Murray Bay, Que., Canada.

June 26-30, 1950 — American Society for Testing Materials, 53rd Annual Meeting and 9th Exhibit of Testing Apparatus and Equipment, Atlantic City, N. J.

August 7-19, 1950 — First United States International Trade Fair, Chicago, Ill.

September 19-21, 1950 — The American Society of Mechanical Engineers, Fall Meeting, Hotel Sheraton, Worcester, Mass.

September 27-29, 1950 — Sixth annual meeting, Canadian Electrical Manufacturers Association, General Brock Hotel, Niagara Falls, Canada.

October 11-14, 1950 — International Association of Electrical Leagues, 15th Annual Conference, Copley Plaza, Boston, Mass.

October 16-20, 1950 — 38th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 17-20, 1950 — National Electrical Contractors Association, Annual Convention, Hotel Biltmore, Los Angeles, Calif.

October 23-27, 1950 — American Institute for Electrical Engineers, Fall General Meeting, Skirvin Hotel, Oklahoma City, Okla.

November 13-16, 1950 — National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

November 26 - December 1, 1950 — The American Society of Mechanical Engineers, Annual Meeting, Hotel Statler, New York, N. Y.

November 27-29, 1950 — American Standards Association, Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

December 3-6, 1950 — The American Society of Refrigerating Engineers, 46th Annual Meeting, Hotel Commodore, New York, N. Y.

Cornhusker Chapter Holds All-Day Lighting Conference

Through good program planning and advance publicity, the Cornhusker Chapter attracted engineers from three states to its all-day lighting conference held April 14 at the Martin Hotel, Sioux City, Iowa.

Church lighting, street lighting and the role played by lighting in architecture were the topics discussed with the group by experts in these fields. Speakers and subjects were:

"Modern Street Lighting Is a Good Investment," by A. G. Ottenheimer, General Electric Co., Chicago, Ill.

"Lighting Is in the Public Eye," by George Gilleard, Curtis Lighting, Inc., Chicago. Stereo Projector showing benefits of lighting installation in three dimensions was introduced.

"Church Lighting," by Edward Rambusch, New York City. A group of Sioux City pastors attended this address.

A social hour sponsored by the city's electrical firms, followed by a dinner and banquet, rounded out this successful and stimulating conference. Harold Spitznagel, Sioux Falls, South Dakota architect addressed the banquet group.

Conference Committee General Chairman was C. R. Tracy, Iowa Public Service Co., aided by M. B. Mendenhall, program; J. J. Bertsch, social hour; William Vahl, Reception; Mark E. Lee, hotel; and George R. Deyo, registration.

WINNIPEG CHAPTER receives Charter (photo at left) in special ceremonies April 13. G. F. Dean (left) made the presentation to the young Chapter's Chairman, E. F. Wilson. In photo at right, Mr. Wilson also receives for the Chapter, a gavel of choice Quebec maple, presented by D. C. Borden (right) on behalf of Quebec Chapter.

Two Outstanding Forums Sponsored by Montreal Section

In cooperation with four other prominent Canadian Associations, the Montreal Section of I.E.S. has presented two exceptionally successful Forums, all-day meetings held April 27, and on May 12, the latter in connection with the Canadian Regional Conference.

The Forum discussion on April 27 covered "Light Conditioning of Educational Premises." Four outstanding papers on various aspects of school lighting were presented:

"Designing for Daylight," by Mr. Watson Balharrie, Abra. Balharrie and Shaw, Architects, Ottawa.

"Daylighting Educational Premises," by Mr. J. Webster, Pilkington Glass Limited, Montreal.

"School Colours," by Mr. L. C. de Belle, Co-Chairman, Colour Committee, Montreal Protestant Central School Board.

"Artificial Lighting of Schools," by Mr. Howard L. Wright, Curtis Lighting Co., Toronto.

Details of the May 12 Forum, on "Light Conditioning in the Home" will be included in the report on the Canadian Regional Conference, next issue. Nine leading home lighting specialists participated.

Co-Sponsors, with the Montreal Section, for both meetings were: The Architects Association of Quebec; The Canadian Paint, Varnish and Lacquer Association; Interior Decorators Society of Quebec; and the Canadian Electrical Association, Wiring Committee.

Advanced Lighting Applications Course Held in Boston

A course for those with a background in lighting techniques and experience in the various phases of lighting was scheduled March 14 through April 18, 1950 by the New England Section of I.E.S.

An outstanding group of speakers from the fields of architecture, engineering, medicine, education and industry were secured to serve as class instructors, each an authority on his subject. An average attendance of over 100 for the six meetings is an interesting indication of the course's success.

The program featured:

1. "Lighting with Relation to Architectural Design," by Charles Burchard, Graduate School of Design, Harvard University.

2. "Changing Concept of Lighting in an Interior," by R. G. Slaner, Sylvania Electric Products, Inc.

3. "Illumination as It Affects Visual Efficiency and Eye Strain," by Dr. Walter B. Lancaster, Boston, Mass.

4. "Industrial Lighting Applications," Walter L. Kelley, New England Machine & Electric Co.

5. "Visual Comfort with Relation to Brightness and Glare," by Phelps Meaker, General Electric Co., Nela Park, Cleveland, Ohio.

6. "School Lighting Applications," by J. L. Kilpatrick, Leader Mfg. Co., New York City. "Office Lighting Practice," by Willard Thompson, Thompson Engineering Co., Boston, Mass.

7. "Store Lighting Applications," by L. S. Cooke, General Electric Co., Lamp Dept.

"Hospital Lighting Applications," by Willard Allphin, Sylvania Electric Products, Inc.

8. "Sports Lighting Applications," by H. N. McIntyre, Illumination Laboratory, General Electric Co., Lynn, Mass.

"Floodlighting Application and Calculations," by J. L. Steffenhagen, Westinghouse Electric Corp.

NEW ORLEANS SECTION received its recently acquired Section Charter officially from President C. H. Goddard (right) on March 13 at President's Night Reception held at Arnauds Restaurant, New Orleans, La. Cecil Pasley (left) Secretary of Section accepts the Charter on behalf of the Section.

Visual Research Specialists Hold Conference

Twenty-four visual research specialists met at Nela Park, Cleveland on April 24-25, for a conference unique in the lighting field. It brought together for a rare meeting, leading researchers whose work is in visual research and who have contributed information closely related to illumination. The conference took the form of an informal discussion during which each researcher described his recent work, stimulating valuable discussion in which others brought their experience and knowledge to bear on the subject. The unanimous reaction to the two-day session was that the conference had been most enlightening and inspirational, and augured well for the development of heightened interest in continuing visual and illumination research.

The subjects presented covered a wide diversity of interest:

"Development of Vision in Infants and Children"—Dr. G. N. Getman.

"Veiling Glare Produced by Stray Light in the Eye"—Dr. Glenn A. Fry.

"Accommodative Factors in Visual Performance"—Dr. S. Howard Bartley.

"An Apparatus for the Measurement of Critical Flicker-Fusion with Some Behavioral Implications"—Dr. Ward C. Halstead.

"Work Miniature Situations"—Dr. Josef Brozek.

"Evaluation of Glare"—Mr. Phelps Meaker.

"Psychophysical Methodology"—Dr. H. Richard Blackwell.

"Illuminant and Background Factors in Vision"—Dr. Harry Helson.

"The Effect of Task-to-Surrounding Brightness Ratios on the Ability to See"—Prof. R. L. Biesele, Jr.

"The Delos Method"—Dr. D. E. Spencer.

"Methods of Measuring Visibility"—Prof. C. L. Cottrell.

"The Relative Visibility Meter"—Mr. A. A. Eastman.

"The Relation Between the Spectral Composition of White Light and Its Efficacy as an Illuminant"—Dr. D. Y. Solandt.

"The I.E.S. Research Program"—C. L. Crouch.

"Visual Stress as a Physiological Problem"—Dr. Ernst Simonson.

"Muscular Tension as a Function of Illumination Level"—Dr. T. A. Ryan.

"Critical Flicker-Fusion as a Function of Illumination"—Dr. M. E. Bitterman.

"Measurement of the Force Exercised by the Extrinsic Ocular Muscles"—Dr. Kurt S. Lion.

"Some Relations of Light to Visually Centered Performance"—Dr. D. B. Harmon.

"Additive Effects of Marginal Conditions on Illumination Requirements"—Dr. Miles A. Tinker.

"Evaluating Ease of Seeing"—S. K. Guth.

Messrs. W. C. Brown and S. K. Guth served as Chairmen of the sessions and as very hospitable hosts.

Pittsburgh Section Conducts Lectures for Architectural Students

Forty-one fourth-year architectural students of Carnegie Institute of Technology attended a series of six illumination lectures during March, sponsored and conducted by the Pittsburgh Section of I.E.S. This was the first time lighting was a feature of the architectural school's instruction on Mechanical Equipment, and indications are that I.E.S. will again be invited to conduct a similar series next year.

The Pittsburgh Section Education Committee also arranged for two lectures on illumination to be part of a weekly seminar conducted for 120 electrical engineering students at the University of Pittsburgh. A lecture on "Light Sources" was given before this group in February; another on "Design and Factors Influencing Design" on April 27.

Offices Demonstrate "Paint With Light" Technique

The district office of the Westinghouse Lamp Division at Chamblee, Ga., near Atlanta, has devised an interesting exhibit that relates lighting and color. Five small offices, lighted by various hues of white fluorescent lamps, appear to be startlingly different, although their walls all are painted the same light green. Robert A. Corvey, lamp district manager, has arranged the display to show visitors

UNIQUE CONFERENCE of visual research specialists met April 24-28 at Nela Park. Those participating were: Front Row (l. to r.) Prof. C. L. Cottrell, Dr. Ernst Simonson, Dr. Harry Helson, Dr. Kurt S. Lion, Dr. M. J. Skeffington, Dr. D. E. Spencer, Dr. J. Howard Bartley, Prof. J. O. Kraehenbuehl, Prof. E. M. Strong. Center Row (l. to r.) S. K. Guth, Dr. M. A. Tinker, Dr. T. A. Ryan, Dr. H. R. Blackwell, Dr. W. C. Halstead, Dr. D. B. Harmon, Dr. A. M. Skeffington, Dr. J. Hall, W. C. Brown. Back Row (l. to r.) Dr. G. A. Fry, Prof. R. L. Biesele, Jr., C. L. Crouch, Dr. G. N. Getman, Dr. D. Y. Solandt, Dr. Josef Brozek, Dr. M. A. Bitterman.

PITTSBURGH Section of I.E.S. Advanced Lighting Course this spring educated 75 men from all branches of the lighting industry in six two-hour sessions covering school, sports, residential and other phases of lighting application.

the dramatic possibilities of "painting with light."

By standing in the general office area, a visitor can see five smaller offices lighted with lamps called standard white, warm white, soft white, 4500° white, and daylight. In the soft white room the walls appear to be grey, in the warm white room they seem yellow green, and in the daylight room they resemble blue walls.

In each room the lighting level is 90 footcandles, about triple the amount of light found in the average office.

For more comfortable seeing conditions, the office filing cabinets were repainted light grey and the old black desk tops were replaced with a mottled white rubber material.

Canadian Electrical Association Announces Data Sheet Contest

To acquire up-to-date information on the many excellent lighting installations that have been made in recent years throughout Canada, and to benefit from the mutual exchange of lighting ideas, The Canadian Electrical Association has announced it would sponsor a lighting data sheet competition in 1950 offering three prizes, $100, $50, and $25. In addition to these awards, the twelve best entries selected for publication in the monthly magazine "Electrical News & Engineering" will receive $10 each.

The contest will be open to all members of the Canadian Electrical Association and to all employees of any Canadian utility company. Entry forms and the rules of the contest are fully explained on data sheets available at the offices of the Canadian Electrical Association, 159 Craig Street West, Montreal, and at all its member companies. Entries must be submitted at the Montreal offices of the C.E.A. by September 15th, 1950.

A.I.E.E. Holds Advanced Lighting Seminar

Repeated requests and favorable comments following the lighting seminar conducted in New York last fall by the American Institute of Electrical Engineers, inspired a new series of lectures this past spring.

Subjects covered at the six weekly meetings, April 25 through May 31, were:

April 25—"Luminous and Louverall Lighting." Speakers: Bernard F. Greene, Consulting Engineer, N. Y.; Alex Sitkin, Voorhees, Walker, Foley & Smith.

May 2—"Vision Research" (continuation of last fall's session). Speakers: Dr. Gertrude Rand, Columbia Presbyterian Hospital; C. L. Crouch, Technical Director, Illuminating Engineering Society.

May 9—"Color in Design." Speakers: William Pahlmann, Interior and Industrial Designer, William Pahlmann Associates, N. Y.; Don Caverly, Sylvania Electric Products.

May 16—"Hot vs. Cold Cathode" "Fluorescent Lighting." Speakers: Jim Forbes, General Electric Co.; Leslie Wax, Cold Cathode Lighting Corp., N. Y.

May 23—"Lighting and Electrical Design." Speakers: Russ Hellegers, Electrical Engineer, Syska & Hennessy; Harry McNary, Fishback & Moore, Electrical Contractor.

May 31—"Street, Highway and Automotive Lighting." Speaker: R. G. Slaner, Sylvania Electric Products Inc., Salem, Mass.

University of Miami Conducts Classroom Study

The first institute on classroom planning to be conducted in Florida was held April 19 and 20 at the Beaumont lecture hall of Miami University. Co-sponsors of the institute were the Southeast Florida Chapter of I.E.S., together with local chapters of A.I.A., the Southeastern Florida Optometric Association, County Health Dept., Teachers Association and Lyons Club.

Dr. Darrell B. Harmon was chief speaker at the several sessions which were attended by many pediatricians, educators, architects, and illuminating engineers.

Invitation Over Seas

Members of the Illuminating Engineering Society resident in the United States or Canada, and who expect to be in England during the month of October, 1950, are invited to consider addressing an audience of the British Illuminating Engineering Society at the Society's Leicester Center (Midland area). Interested and qualified persons should correspond directly with Honorary Secretary, B. V. Rowe of the Illuminating Engineering Society, c/o G. E. Company, Ltd., Westbridge, Leicester, England. Please do not correspond with I.E.S. headquarters in New York City through which this invitation is relayed at Mr. Rowe's request.

Permanent Store Modernization Center Planned in New York City

Plans for the establishment of the first Store Modernization Center, aimed at centralizing interest in new store equipment and building materials, were announced recently by John W. H. Evans, Director of the Store Modernization Institute, sponsor of the Store Modernization Shows held the past three years.

The center will house permanent exhibits of store modernization materials, and negotiations are now under way to lease 15,000 square feet of floor space in an air-conditioned building on Fifth Avenue, New York City, to serve as headquarters for the project. Exhibits will be open five days a week throughout the year to executives of retail stores and store architects and designers and builders engaged in the modernizing of stores, felt to be one of the most active building classifications in America.

A survey of 17 major buying offices

in New York, representing more than 1,500 of the largest department stores in the United States, indicates popular acceptance of the idea, according to Mr. Evans, who disclosed that 86,000 buyers and merchandise managers visited New York last year to purchase merchandise for their stores.

Present plans call for a well-rounded continuous program of activities at the Store Modernization Center. Clinics and forums will be held monthly and will present discussions by leading architects, designers, store executives and equipment manufacturers on such topics as design and layout, displays and fixturing and merchandise handling techniques. Retailers throughout the country will be invited to these meetings. Prominent store architects and designers from all states will be invited each month to exhibit their best completed work of newly modernized stores.

New Motion Picture Arc Lamp

A revolutionary type of high-intensity motion picture arc lamp, employing a very thin slowly rotating wheel as a negative carbon and suction pipes to prevent the formation of "mushroom" deposits, and using an air blast to concentrate the anodic flame, was described at the recent 67th semi-annual convention of the Society of Motion Picture and Television Engineers at the Drake Hotel, Chicago.

The new lamps, recently developed in Zurich, Switzerland, are designed to permit maximum values of crater brilliancy and screen lumens, according to Dr. Edgar Gretener of Zurich, who demonstrated the equipment at a convention session.

The maximum screen lumen value is not yet known, Dr. Gretener said, and may be as high as 50 to 60 thousand lumens. As many as 15 thousand lumens are available, with a "side to center" distribution of 80 per cent, with the 50-ampere lamp now in production in Switzerland, he said, while a 100-ampere type is now ready for production and will provide up to 30 thousand lumens, with the same distribution.

In conventional high-intensity mirror lamps, the arc becomes unstable with an extremely high current load, and the admissible consumption rate cannot exceed a certain limit with respect to the necessary burning time of 20 minutes, according to Dr. Gretener. The unique features of the new lamps, he explained, are designed to overcome these limitations. The air blast used to concentrate the anodic flame in the lamp is projected from the housing of the positive carbon. A coil near the tip of the carbon rotates the arc around its own axis several hundred times per second. A special lens and photo cell arrangement uses the image of the crater edge to operate a magnetic clutch which governs the positive carbon feed.

Exhibit Train Dedicated

The General Electric Company unveiled its More Power to America Special, the biggest electrical display kit ever built, in Grand Central Terminal, New York City, April 24.

Almost a quarter-mile long, the 10-car exhibit train represents the first attempt to display, in one series of related exhibits, the complete range of products for the production, distribution, and industrial utilization of electric power.

Believed to be unique in industrial marketing history, the silver streamliner is filled with exhibits of more than 2,000 of the most modern electric products, systems, and techniques.

The "Special," launched on the rails by the company's Apparatus Department, was in New York on the first lap of a nation-wide tour. It will visit approximately 150 key industrial centers during 1950 and 1951.

The train will not be open to the general public, according to G-E spokesmen. They explained that the exhibits aboard the train have been designed specifically to interest those who produce electric power and those who put it to work in industry and the community.

Exhibits in the "Special" are grouped in 11 major sections: Industrial Lighting, Power Generation, Transmission, and Distribution; Drives and Controls, Materials Handling, Welding, Industrial Heating, Renewal Parts, Components for Industry, Measurements, Civic Improvement, and National Security.

McGraw-Hill Announces Periodical Microfilm Service

The McGraw-Hill Publishing Company, 330 West 42nd Street, New York, N. Y., has entered into an agreement with University Microfilms, Ann Arbor, Mich., to make available to libraries issues of a number of McGraw-Hill publications in microfilm form.

One of the most pressing problems facing all types of libraries today is that of providing adequate space for a constant flood of publications. Periodicals pose an especially difficult problem because of their bulk and number.

Microfilm makes it possible to produce and distribute copies of periodical literature on the basis of the entire volume in a single roll, in editions of 30 or more, at a cost approximately equal to the cost of binding the same material in a conventional library binding.

Under the plan, the library keeps the printed issues unbound and circulates them in that form for from two to three years which corresponds to the period of greatest use. When the paper copies begin to wear out or are not called for frequently, they are disposed of and the microfilm is substituted.

Sales are restricted to those subscribing to the paper edition, and the film copy is distributed only at the end of the volume year.

The microfilm is in the form of positive microfilm, and is furnished on metal reels, suitably labeled. Inquiries concerning purchase should be directed to University Microfilms, 313 N. First Street, Ann Arbor, Mich.

June Deadline Misses Four Important Regional Conferences

The exigencies of publication deadlines has prevented this month's issue of Telecast carrying a report on four excellent Regional Conferences held during May. These were the Canadian Regional Conference, held in Montreal May 11-12. The East Central Regional Conference, Philadelphia, May 18-19. The Mid-western Regional Conference in Milwaukee, May 17-19. The Great Lakes Regional Conference in Buffalo, May 22-23.

Details of these important I.E.S. Conferences, will be a feature of the Telecast Section, next issue.

IT SEEMS TO ME

Editorial Screening

To the Editor:

On page 203 of the March 1950 issue of ILLUMINATING ENGINEERING there appears a letter adressed to you by Mr. M. H. Bruesewitz of the Wisconsin Electric Power Co., Milwaukee, Wisconsin. Mr. Bruesewitz makes a point of constructively criticizing the quality of some of your advertisements. He is to be commended on the fact that he brings to the attention of the editor a noticeable conflict between the enlightening data in the many technical articles compared with the message behind some of the advertisements.

On page 2A of the same issue there appears an "ad" together with a photo of a furniture store. Amidst much text under the photo, the advertiser states "Note the eveness of illumination ... the absence of shadows ... the ease of seeing ... all of which make a good lighting installation." Any lighting man having had experience in lighting and merchandising furniture, quickly sees the confusion these claims would lead to.

The progressive approach to lighting furniture showrooms, brings into use light sources with good directional component rather than diffuse light sources. A furniture buyer first satisfies his functional needs most of the time, and then considers fabric, texture, color and form. Since furniture has three dimensions, what light source other than a concentrated one would emphasize its shape and form? A diffuse light source creating no shadows, renders objects flat and monotonous. Modern furniture designers regard much of their work as sculpture put to practical use; and they conceive much of their work under the play of lights and shadows. The weavers of textured fabrics would surely join the rebellion against diffuse and monotonous lighting. Most of us know that the directional light source also enhances the appearance of a fabric. Dramatic lighting is surely the answer to furniture display.

If one turns to page 8A of this same issue, one sees an "ad" recommending certain equipment for office lighting. If the photo suggests that the office area illustrated is properly lighted, then it becomes necessary to rewrite the "Recommended Practice for Office Lighting." The photo gives no evidence of comfortable visual environment. The ceiling is obviously dark. There is evidence of extreme contrast between the lenses and the acoustical ceiling. The desk tops show unusually low brightness. Other than the lenses, the highest brightness in the office is on the front side of the desks; no doubt the artificial lighting added by a photographer. Moon & Spencer would have no difficulty in finding that the helios in the shadow areas was in excess of 10 per cent of that of other areas. The photo certainly fails to illustrate good office lighting practice.

Perhaps it has occurred to other readers that the series of Lighting Data Sheets are often antiquated and unimaginative. Series XV 3-50 on page 154 is a case in point. What is so unusual about the data and photograph that it rates a full page? By simply looking at the cross section, one can see that the lamps become a reflected glare source in the glass brick. I would say that this information does not conform to Recommended Practice. Surely this space could be used for a thousand more important uses.

Most of us look forward eagerly to each new issue of ILLUMINATING ENGINEERING. I have learned to regard it as more valuable than any text book heretofore published. It would seem to me that the editors should screen the advertisements and Lighting Data Sheets to be sure that the message contains information which will be informative, and which conforms to the high standards of the Society. Propaganda and meaningless data have no place in an engineering publication.—H. M. GERSTEL, *Gotham Lighting Corporation, New York City.*

EDITOR'S NOTE:

With reference to Mr. Gerstel's concluding points: (1) prevailing American publication practice precludes editorial dictation of what advertisers can say in the advertising space which they pay for. However, I.E.S. advertisers and their agencies are subject to the continuing editorial urge that they improve their advertising copy in ILLUMINATING ENGINEERING by presenting therein carefully screened useful technical information pertaining to the application of the advertised products; (2) the selection of topic and subject matter for lighting data sheets is the responsibility and prerogative of the I.E.S. Sub-Committee on Lighting Data Sheets.

Schoolroom Brightness Limitations

To the Editor:

Page 241 of the April issue of ILLUMINATING ENGINEERING brings something to my attention as a Sales Manager which has bothered me quite a little bit.

Time and time again, I have maintained that the lighting industry has quite a tendency to try and sell down even though the consumer was doing his best to sell up. I refer to the discussion on the page I mentioned where apparently a school man is interested in quality and willing to buy it but our own industry is trying to convince him that he should buy something other than quality.

Maybe I am wrong and would be pleased to listen to the other side of the question, remembering that my criticism is based on sales only, not engineering.—F. I. WILSON, *Sales Manager, F. W. Wakefield Brass Co., Vermilion, Ohio.*

To the Editor:

Recent discussion both published and unpublished of our paper "Application of Recommended Brightness Limitations to School Classrooms," indicate there is some misunderstanding regarding our feelings about quality lighting. We are, therefore, writing this open letter to clarify some of our statements, which we believe are being misinterpreted.

The controversy revolves around a single statement that we made in describing the characteristics of plastic bottom luminaires. After telling how good the lighting was with such an installation, we stated, "Many school officials feel, however, that the advantage provided by such an installation is more than offset by its higher cost, lower illumination level, and greatly increased maintenance problem." We stated this as a fact and no one has disputed it. The sentence possibly would have been better if it had read, "Many school officials find, however, that they cannot afford this increased comfort because of its higher cost, lower illumination level, and a greatly increased maintenance problem." We call particular attention to the following statement, which we made in the

Summary a few sentences later: *"Certainly a function of the lighting industry is to convince school officials and those charged with the specification of equipment for classroom lighting that the increased benefits of quality lighting justify its higher cost."* Perhaps this sentence should have immediately followed our remark about the school officials, but we could not foresee the need for such juxtaposition at the time we wrote the paper. To us this seems to be a minor technicality.

Remembering now that ILLUMINATING ENGINEERING is essentially an internal organ of the Society, we feel that it is proper and desirable to set forth all of the facts in our technical papers and discussions. These facts at times conflict with our ideals, but nevertheless, we must face reality. It is fine for our Society to establish standards and guides that will give the consumer assurance of *really good* lighting. We must do our best to promote such lighting, but we should not completely turn our backs upon those who will not or can not install such lighting for one reason or another. We must provide reasonable and practical alternate guides that these people can use and be assured of reasonably good results. Otherwise, they are apt to make installations that are completely unsatisfactory and do more harm than good. This feeling was echoed by the I.E.S. School Lighting Committee when they sanctioned an alternate set of doubled luminaire brightness limits in the "American Standard Practice for School Lighting." Our only issues with this committee's work are (1) they did not specify how the brightness was to be measured, and (2) the limits imposed failed to recognize luminaire performance characteristics by a small margin. This margin is so small that the necessary increase over their recommended acceptable maximum for the reflected glare zone would not be perceptible to the eye. — JOHN J. NEIDHART, and F. C. WINKLER, *Westinghouse Electric Corp., Cleveland, Ohio.*

NEW MEMBERS

At the meeting of the Council Executive Committee held in Montreal, Canada, on May 10, 1950, the following were elected to membership:

ALAMO CHAPTER

Associate Member:
Carson, Ray, Sylvania Electric Products Inc., Kansas City, Mo.

BRITISH COLUMBIA SECTION

Associate Member:
Hall, M. J., Marshall Wells B. C., Ltd., Vancouver, B. C., Canada

Student Members:
Adams, H. F. R., University of British Columbia, Vancouver, B. C., Canada
Sinclair, K. I., University of British Columbia, Vancouver, B. C., Canada

CAROLINAS CHAPTER

Associate Members:
Baker, R. H., Graves Electric Supply Co., Greenville, S. C.
Black, H. G., Graves Electric Supply Co., Greenville, S. C.
Elliott, R. E., Johannesen Electric Co., Inc., Greensboro, N. C.
Keller, J. A., Jr., Sullivan Hardware Co., Greenville, S. C.
Rice, G. M., Huntington & Guerry Electric Co., Greenville, S. C.
Rutledge, J. R., Huntington & Guerry Electric Co., Greenville, S. C.

CENTRAL NEW YORK CHAPTER

Student Members:
Buyer, L. E., Cornell University, Ithaca, N. Y.
Rabkin, R. M., Cornell University, Ithaca, N. Y.

CHICAGO SECTION

Associate Members:
Levine, A. S., Sola Electric Co., Chicago, Ill.
Meier, E. W., Chicago Park District, Chicago, Ill.
Oberheltzer, J. R., Chicago Park District, Chicago, Ill.
Robinson, D. D., Westinghouse Lamp Division, Chicago, Ill.
Weeks, F. D., Joslyn Mfg. & Supply Co., Chicago, Ill.
Witte, E. H., Benjamin Electric Mfg. Co., Des Plaines, Ill.

CLEVELAND SECTION

Member:
Barney, C. W., The Austin Co., Cleveland, Ohio

Associate Members:
Greenlee, P. H., General Electric Co., Nela Park, Cleveland, Ohio
Leppelmeier, E. T., General Electric Co., Nela Park, Cleveland, Ohio
Maier, D. P., Western Reserve University, Cleveland, Ohio
Maurer, W. J., McGeorge-Hargett & Associates, Cleveland, Ohio
Smith, R. L., Holophane Co., Inc., Newark, Ohio

Student Member:
Faile, F. E., Case Institute of Technology, Cleveland, Ohio

CONNECTICUT SECTION

Member:
White, C. K., Grand Light & Supply Co., New Haven, Conn.

Associate Members:
Gowans, R. H., Hartford Fire Insurance Co., Hartford, Conn.
Kruse, R. W., Rohm and Haas Co., Philadelphia, Pa.
Wrinn, J. J., Wrinn Electric Co., Colchester, Conn.

CORNHUSKER CHAPTER

Associate Members:
Blazek, D. R., Consumers Public Power District, Lincoln, Neb.
Gilbert, W. L., Board of Education, Sioux City, Iowa
Kenworthy, P. H., Kenworthy Electric Co., Omaha, Neb.

EASTERN PENNSYLVANIA CHAPTER

Associate Member:
Smith, D. D., Lacy, Atherton and Davis, Wilkes Barre, Pa.

FOREIGN NON-SECTION

Associate Members:
Meneses, F. H., Lumenes, S. A., Virtudes #867, Havana, Cuba
Wong, W. H., Paradise Electric Co., 1470 Kapiolani Blvd., P.O. Box 1637, Honolulu, Hawaii

GEORGIA SECTION

Members:
Harrison, P. P., Sylvania Electric Products, Inc., Atlanta, Ga.

VISITORS to the Southern California National Technical Conference in Pasadena, August 21-24, will be offered the opportunity of seeing many high quality lighting installations. The steel fabrication area in the U. S. Spring and Bumper Co. plant in Vernon, California, shown above, is an outstanding installation using 100-watt fluorescent lamps (two per fixture) developing a maintained lighting level of 50 footcandles.

The above photograph has at least two features of direct interest to I.E.S. members. 1. The gentleman apparently Geiger-counting the emanation from the lighting units is E. E. (Ernie) Wakefield, long a well known member of I.E.S., now Director of the Radiation Laboratories, Inc., Chicago. 2. The fluorescently lighted atomic truck operated as a mobile radiochemical laboratory to visit all major research laboratories in the U.S. The truck is illuminated, to a level of 65 footcandles, by four lighting fixtures, each of which has two 4-foot fluorescent lamps operating at 120 volts. Source of power is through a cable which connects to an outlet at the laboratory visited. Reflection factor of the ceiling and walls is 80 per cent; desk tops are green, and the floor is gray per reflection factor of 45 per cent.

Mitchell, J. D., Jr., Westinghouse Electric Corp., Chamblee, Ga.
Tucker, W. T., Georgia Power Co., Rome, Ga.

HEART OF AMERICA SECTION

Members:
Seburn, T. J., 414 E. 12th St., Kansas City, Mo.

Associate Members:
Roberts, W. H., Columbian Electrical Co., Kansas City, Mo.
Sinovich, John, Evans Electrical Construction Co., Kansas City, Mo.
Weir, J. M., W. T. Foley Electric Co., Kansas City, Kansas.

INDIANA CHAPTER

Associate Members:
Jenkins, W. F., Municipal Electric Lighting & Power Plant, Richmond, Ind.
Lagle, R. L., General Electric Supply Corp., Indianapolis, Ind.
Miles, Earl F., Jr., Sperti Faraday, Inc., Indianapolis, Ind.

IOWA SECTION

Associate Members:
Ahlquist, R. W., Iowa State College, Ames, Iowa
Comer, J. G., Electric Supply Co., Des Moines, Iowa
Wilder, V. E., Delavan Engineering Co., Des Moines, Iowa

MICHIGAN SECTION

Member:
Lake, R. C., The Pelton & Crane Co., Detroit, Mich.

Associate Members:
Plante, G. J., Smith Bros. Electric, Inc., Detroit, Mich.
Olson, Arnold, S. S. Kresge Co., Detroit, Mich.
Robbins, H. R., General Electric Co., Detroit, Mich.

MILWAUKEE CHAPTER

Associate Members:
Byington, G. R., Wisconsin Power & Light Co., Madison, Wis.
Godschalx, A. T., Square "D" Co., Milwaukee, Wis.
Little, C. H., General Electric Supply Corp., Jackson, Miss.
Owen, C. T., Carl C. Crane, Inc., Madison, Wis.
Tranton, E. W., Northern Light Co., Milwaukee, Wis.

Student Members:
Schnoll, Edwin, University of Wisconsin, Madison, Wis.
Schultz, A. H., University of Wisconsin, Madison, Wis.

MISSISSIPPI CHAPTER

Student Member:
Richardson, E. K., Mississippi State College, State College, Miss.

MOTHER LODE CHAPTER

Associate Member:
Holm, E. N., Sacramento Municipal Utility District, Sacramento, Calif.

NEW ENGLAND SECTION

Associate Member:
Wheelock, W. T., General Electric Co., Pittsfield, Mass.

NEW YORK SECTION

Member:
Krumhout, J. C., Sylvania Electric Products, Inc., New York, N. Y.

Associate Members:
Fonda, G. E., Dr., 6 Parkview Drive, Millburn, N. J.
Morrow, George, Sylvania Electric Products, Inc., New York, N. Y.

Student Members:
Albanese, P. R., City College of New York, New York, N. Y.
Sher, Arnold, City College of New York, New York, N. Y.
Skorka, Irving, City College of New York, New York, N. Y.
Sleisinger, J. L., College of the City of New York, New York, N. Y.

NORTHERN CALIFORNIA SECTION

Associate Member:
Wilder, H. K., National Canners Association, San Francisco, Calif.

OHIO VALLEY SECTION

Student Members:
Hartner, R. K., University of Dayton, Dayton, Ohio
Grenoffeo, R. H., Jr., University of Dayton, Dayton, Ohio
Hoeffel, T. L., University of Dayton, Dayton, Ohio
Suttman, L. L., University of Dayton, Dayton, Ohio
Thome, R. J., University of Dayton, Dayton, Ohio
Thompson, J. P., University of Dayton, Dayton, Ohio
Vehr, T. J., University of Dayton, Dayton, Ohio
Wannemacher, H. H., University of Dayton, Dayton, Ohio
Wendeln, M. E., University of Dayton, Dayton, Ohio

OREGON SECTION

Associate Members:
Baker, L. J., Portland Public Schools, Portland, Ore.
Krivanhek, J. T., Jr., Krivanhek Electric Co., Longview, Wash.
Strueber, R. F., General Electric Supply Corp., Portland, Ore.
White, C. C., Jr., Myers & White, Portland, Ore.

Student Members:
Bond, B. W., Pacific University, Forest Grove, Ore.
Brown, R. D., Pacific University, Forest Grove, Ore.
Burrell, C. A., Pacific University, Forest Grove, Ore.
Coburn, G. E., Pacific University, Forest Grove, Ore.
Cowherd, C. W., Pacific University, Forest Grove, Ore.
Hamm, D. C., Pacific University, Forest Grove, Ore.
Hedrick, R. P., Pacific University, Forest Grove, Ore.
Henderson, G. W., Pacific University, Forest Grove, Ore.
Janecky, C. H., Pacific University, Forest Grove, Ore.
Kirk, F. N., Pacific University, Forest Grove, Ore.

OTTAWA CHAPTER

Associate Members:
Anderson, R. G., Canadian Federal Government, R.C.A.F., Dept. of National Defense, Ottawa, Ont., Canada
Moore, J. E., Rest-Glow Mfg. Co., Ltd., Ottawa, Ont., Canada

PHILADELPHIA SECTION

Members:
Huch, W. C., Jr., Philadelphia Electric Co., Philadelphia, Pa.
Lauer, T. W., Ramsey Electric Co., Philadelphia, Pa.
Mosey, L. W., 3rd, Keller Pike Co., Philadelphia, Pa.
Stratton, M. W., Independent Wiring Co., Inc., Philadelphia, Pa.

Associate Member:
Abromeit, Edward, 7331 Bingham St., Philadelphia, Pa.

Student Member:
Ronkin, S. M., Pennsylvania State College, State College, Pa.

PITTSBURGH SECTION

Associate Members:
Gloekler, W. C., Jr., Star Electric Co., Pittsburgh, Pa.

Continued on page 193

SUSTAINING MEMBERS

Acme Electric Corp.
Cuba, N. Y. *J. A. Comstock*

Admiral Lamp Manufacturing Corp.
2430 So. Ashland Ave., Chicago, Ill. *F. Schwartz*

Advance Transformer Co.
1122 W. Catalpa Ave., Chicago 40, Ill. *Hirsch Epstein*

Alabama Power Co.
Birmingham, Ala. *George L. Morris*

All Bright Electric Products Co.
3917-25 N. Kedzie Ave., Chicago 18, Ill. *Max Klein*

Aluminum Company of America
Gulf Building, Pittsburgh 19, Pa. *C. Braglia*

Amalgamated Electric Corp., Ltd.
994 Pape Ave., Toronto, Ont., Canada *D. W. Patterson*

American Concrete Corp.
4727 North Lamon Ave., Chicago 30, Ill. *J. W. Lewis*

American Fluorescent Corp.
5407 Broadway, Chicago, Ill. *William Rusnak*

American Sterilizer Co.
Erie, Pa. *Horace Wm. Alexander*

Appleton Electric Co.
1701-1729 Wellington Ave., Chicago 13, Ill. *Nils A. Tornblom*

Arkansas Power & Light Co.
Simmons National Bldg., Pine Bluff, Ark. *Max Buddath*

The Art Metal Co.
1814 E. 40th St., Cleveland 3, Ohio *George E. Glatthar*

Artistic Lamp Manufacturing Co., Inc.
995 Fourth Ave., New York 16, N. Y. *Myron Perlmutter*

Bausch & Lomb Optical Co.
Rochester 2, N. Y. *Arthur E. Neumer*

Benjamin Electric Mfg. Co.
Des Plaines, Ill. *John H. Waterbury*

Blue Ridge Glass Corp.
P.O. Box 631, Kingsport, Tenn. *James Herbert*

Board of Water and Electric Light Commissioners
116 W. Ottawa St., P.O. Box 570, Lansing 9, Mich. *John D. Mulvihill*

Boston Edison Co.
39 Boylston St., Boston 13, Mass. *R. B. Brown, Jr.*

Branham, Marsch & Duepner, Inc.
7020 Walker St., St. Louis Park, Minneapolis 16, Minn. *Cecil H. Branham*

Bright Light Reflector Co., Inc.
Fairfield & State, Bridgeport 5, Conn. *C. E. Scholl*

British Columbia Electric Rwy. Co., Ltd.
970 Dunsmuir St., Vancouver, B. C., Canada *H. N. Walters*

Brockton Edison Co.
36 Main St., Brockton 67, Mass. *W. A. Forbush*

Buffalo Niagara Elec. Corp.
Buffalo 3, N. Y. *Jack F. Parsons*

Edward F. Caldwell & Co., Inc.
101 Park Ave., New York 17, N. Y. *E. T. Caldwell*

California Electric Power Co.
P.O. Box 813, Riverside, Calif. *W. E. Vaughn, Jr.*
Ralph G. Raymond

Cal-Lite, Inc.
12600 S. Yukon Ave., Hawthorne, Calif. *N. L. Urolas*

Calpa Products Co.
4116 Chester Ave., Philadelphia 4, Pa. *Paul C. Calisi*

Cambridge Electric Light Co.
46 Blackstone St., Cambridge 39, Mass. *Reginald H. Bowman*

Canadian General Elec. Co., Ltd.
212 King St., Toronto, Ont. *R. M. Love*

Canadian Laco Lamps, Ltd.
745 Guy St., Montreal, Que. *J. Thomas*

Canadian Line Materials, Ltd.
Postal Station H, Toronto 13, Ont., Canada *L. E. Messinger*

Central Hudson Gas and Elec. Corp.
50 Market St., Poughkeepsie, N. Y. *H. E. Dexter*

Central Illinois Light Co.
316 Jefferson Ave. S., Peoria 2, Ill. *R. K. Dallas*

Central Illinois Public Service Co.
607 E. Adams St., Springfield, Ill. *B. L. Paim*

Central Maine Power Co.
9 Green St., Augusta, Maine *Roland W. Hess*

Central New York Power Corp.
300 Erie Boulevard W., Syracuse, N. Y. *L. D. McCormac*

Central Power & Light Co.
P.O. Box 2121, Corpus Christi, Texas *James M. Williams*

Champion Lamp Works Div. of Consolidated Electric Lamp Co.
600 Broad St., Lynn, Mass. *Ellery H. Raddin*

Cincinnati Gas & Electric Co.
Fourth & Main Sts., Cincinnati 1, Ohio *J. R. Hartman*

Circlite Corp.
118 So. Clinton St., Chicago, Ill. *George Gomberg*

City of Burbank, California Public Service Department
174 W. Magnolia Boulevard, Burbank, Calif. *J. H. McCambridge*

City of Glendale Public Service Dept.
119 N. Glendale Ave., Glendale 6, Calif. *H. E. Gulick*

City of Riverside Electric Light Dept.
3854 Mulberry St., Riverside, Calif. *L. W. Grayson*

City of Seattle, Dept. of Lighting — Puget Sound
1015 Third Ave., Seattle 4, Wash. *P. C. Spowart*

City of Tacoma, Light Division
402 City Hall, Tacoma 2, Wash. *Roy H. Weston*

The Cleveland Electric Illuminating Co.
75 Public Square, Cleveland 1, Ohio *R. C. Hienton*

Colonial Electric Products Co., Inc.
1115 Market St., E. Paterson, N. J. *Wallace M. Woodworth*

Colonial Premier Co.
466 W. Superior St., Chicago 10, Ill. *Richard Weis*

Columbia Electric & Mfg. Co.
1024 West 1de Ave, Spokane, Wash. *Walter A. Toly*

Commercial Light Co.
841 W. Washington Blvd., Chicago, Ill. *Michael R. Pino*

Commonwealth Edison Co.
72 W. Adams St., Chicago 90, Ill.

The Connecticut Light & Power Co.
250 Freight St., Waterbury 91, Conn.

Consolidated Edison Co. of N. Y., Inc.
4 Irving Place, New York 3, N. Y. *Thomas J. Collins*

Consolidated Gas, Elec. Light & Power Co. of Baltimore
100 W. Lexington St., Baltimore 1, Md. *M. C. Albrittain*

Consumers Power Co.
212 Michigan Ave. W., Jackson, Mich. *D. E. Karn*

Consumers Public Power Co.
1452-25th Ave., Columbus, Nebraska *W. H. Sinks*

Corning Glass Works
Corning, N. Y. *A. S. Tyler*

Coyne Electrical School, Inc.
500 So. Paulina St., Chicago 7, Ill. *John Hanon*

Crescent Electric Supply Co.
765 Iowa St., Dubuque, Iowa *Titus B. Schmid*

Crouse-Hinds Co.
Syracuse 1, N. Y. *A. H. Clarke*

Crouse-Hinds Co. of Canada, Ltd.
7 Labatt Ave., Toronto, Ont. *F. R. Jeffery*

Curtis Lighting, Inc.
6135 W. 65th St., Clearing Station, Chicago 38, Ill. *Darwin Curtis*

Curtis Lighting of Canada, Ltd.
195 Wicksteed Ave., Leaside, Toronto 17, Ont. *H. L. Wright*

Cutler Light Manufacturing Co.
2026-29 N. 22d St., Philadelphia 21, Pa. *Robert T. Cutler*

Dallas Power & Light Co.
1506 Commerce St., Dallas 1, Texas *W. G. Moore*

Day-Brite Lighting, Inc.
5401 Bulwer St., St. Louis 7, Mo. *D. J. Biller*

The Dayton Power & Light Co.
25 No. Main St., Dayton, Ohio *H. S. Nonnaman*

Dazor Manufacturing Corp.
4482 Duncan Ave., St. Louis 10, Mo. *P. L. Read*

Delaware Power & Light Co.
600 Market St., Wilmington 99, Del. *W. A. F. Pyle*

Dept. of Water & Power, City of Los Angeles, Bur. of Power & Light
Box 3669 Terminal Annex, 207 So. Broadway, Los Angeles 54, Calif. *C. P. Garman*

Detroit Edison Co.
2000 Second Ave., Detroit 26, Mich. *L. E. Taylor*

Detroit Electrical Contractors Association
627-628 Hotel Book Cadillac, Detroit 26, Mich. *Carl J. Schoeninger*

Detroit Steel Products Co.
2250 E. Grand Blvd., Detroit 11, Mich. *W. Clifton Randall*

E. I. duPont de Nemours & Co., Inc. (Fabrics & Finishes Div.)
Wilmington 98, Del. *E. W. Quisenberry*

E. I. du Pont de Nemours & Co., Inc. Polychemicals Dept.
Wilmington 98, Del. *E. E. Leary*

Duquesne Light Co.
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Duro Test Corp.
2321 Hudson Blvd., North Bergen, N. J. *James L. Cox*

Eastern Fixture Co., Inc.
170 Vernon St., Boston 20, Mass. *Louis Gilman*

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Ebasco Services, Inc.
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W. N. Dudley

Electrical Testing Laboratories, Inc.
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5849 Boyer St., Montreal, Que., Canada.
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Ender Manufacturing Corp.
260 West St., New York 13, N. Y.
Jules Lowenstein

Electron Corp.
4801 Galapago, Denver, Colo. *Floyd Vickers*

Englewood Electrical Supply Co.
5601-03 So. Halsted St., Chicago, Ill.
Ray O'Leary

Famous Fluorescent Light Co.
762 N. Ogden Ave., Chicago 22, Ill.
Jack E. Stone

Federal Electric Company, Inc.
8700 S. State St., Chicago, Ill.
John H. Goshat

Fitchburg Gas & Electric Light Co.
537 Main St., Fitchburg, Mass. *A. G. Neal*

Fluorescent Equipment & Mfg. Co.
2570 Superior Ave., Cleveland 14, Ohio
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Fluorescent Maintenance Co., Inc.
1480 S. Robertson Blvd., Los Angeles 35, Calif. *Leonard E. Black*

Fluores-O-Lite Co.
Evans Terminal, No. Broad St., Hillside, N. J.
Meyer H. Silverman

The Fostoria Pressed Steel Corp.
Fostoria, Ohio *E. L. Bates*

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Stanley A. Framburg

The France Mfg. Co.
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J. H. Mayne

The Frankelite Co.
1425 Rockwell Ave., Cleveland 14, Ohio
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Franklin Design Service, Division of Safeway Stores, Inc.
4th & Jackson Sts., P.O. Box 660, Oakland 4,
Wallace H. Lane

The Frink Corporation
27-01 Bridge Plaza North, Long Island City, N. Y. *Theo. J. Brassel, Jr.*

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Nela Park, Cleveland 12, Ohio
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General Electric Supply Corp.
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General Lighting Products Co.
468 Prelinghuysen Ave., Newark 5, N. J.
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397 Seventh Ave., Brooklyn, N. Y.
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H. E. Ingraham

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P.O. Box 1700, Houston 1, Texas
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Bert C. Pretzer

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United Light Bldg., Davenport, Iowa
John M. Hollingsworth

Iowa Public Service Co.
400 Commercial St., Waterloo, Iowa
C. R. Wagoner

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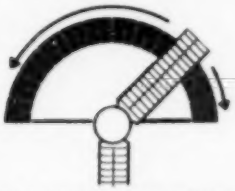
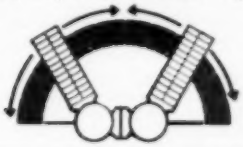
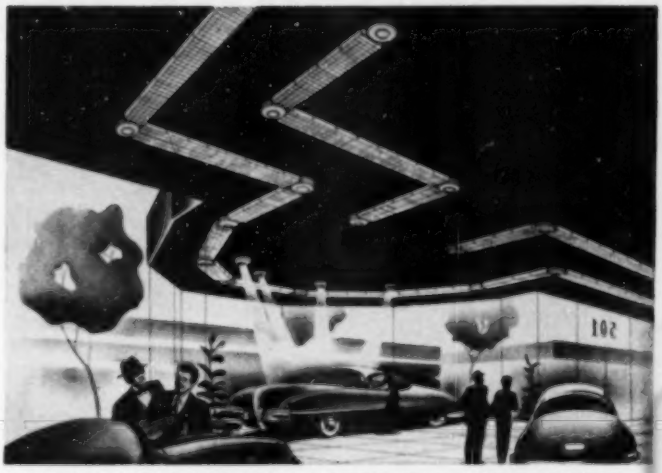


SIMPLE, PRACTICAL PRINCIPLE

Three basic elements form the PLEXOLINE system: 1. Linear section; 2. Circular accent unit; 3. Adapter fitting. The two illustrations show how the elements are used in combination to form any lighting pattern desired. All elements are complete in themselves, may be used individually.





PLEXOLINE AND IMAGINATION—AN UNBEATABLE SELLING COMBINATION!

Never before such wonderful possibilities for store and showroom lighting! Dramatic, beautiful PLEXOLINE creations put light where you want it . . . how you want it! Straight linear sections for offices, schools, colleges, banks, public buildings.

DAY-BRITE'S Plexoline

THE ONLY LIGHTING SYSTEM WITH TRULY UNLIMITED "FLEX-ABILITY"

What does PLEXOLINE mean to you? It means new freedom for your imagination. It means a line of light following a gently curving wall contour . . . angular patterns of light . . . circles . . . *any* design. It means—for the first time in history—all the advantages of custom-lighting with all the economies of a mass-produced system of fixtures.

Today, send for the whole amazing story of PLEXOLINE. Fill out and mail the coupon below. See for yourself what PLEXOLINE's unique "flex-ability" can do for you!

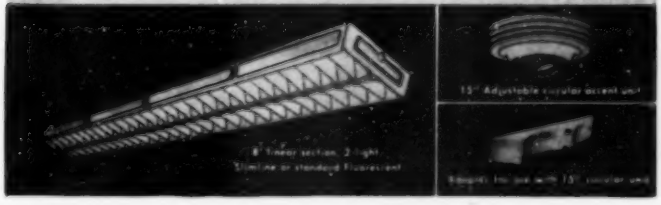
THE PLEXOLINE SYSTEM

LINEAR SECTIONS—For Slimline and standard Fluorescent, 2- and 4-light, 4', 6', and 8' lengths, surface or suspension mounted. Alballte glass side panels, interlocked steel louvers, finished in HOT-BONDED SUPER WHITE enamel.

CIRCULAR ACCENT UNITS—15" and 21" diameter, with fixed Controlens® or adjustable spot mechanism. Luminous sides. Surface mounted only.

ADAPTERS — Uniform, die-formed, all-steel—in two sizes to fit circular units.

®Holophane Co.



"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

029

Day-Brite Lighting, Inc.
5432 Bulwer Ave., St. Louis 7, Mo.
In Canada: Amalgamated Elec. Corp., Ltd., Toronto 6, Ontario

Please send me your FREE booklet, "PLEXOLINE—IMAGINATION AT WORK"

Name .....

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City ..... State .....

VISIBILITY UNLIMITED—

WITH PLEXIGLAS QUALITY LIGHTING

A Lighting Fixture As Big As The Room. PLEXIGLAS diffusing panels in control room of Philadelphia Electric Company generating station. Large sections of white translucent PLEXIGLAS, installed wall-to-wall below cold cathode tubes, give excellent glare-free illumination.

Three things happen when you install PLEXIGLAS Lighting Fixtures:—

Glare and eyestrain take a permanent holiday.
Personnel efficiency and morale go kiting.
Lighting maintenance tumbles to a new low.

White translucent PLEXIGLAS diffuses light so completely that glare simply vanishes. Brightness ratios are remarkably low, yet minimum absorption and maximum transmission of light give full, even illumination throughout any room. Maintenance costs are negligible because PLEXIGLAS is light, strong, shatter-

EYESTRAIN ZERO

No Glare—No Shadows. Installed by Texas Electric Service Co., Fort Worth, in their own sales office, this wall-to-wall luminous ceiling gives glare-free, completely diffused illumination throughout the room. Footcandle reading is 99, *with* diffusing panels—110 *without* panels. This remarkable efficiency is possible only because white translucent PLEXIGLAS absorbs no light. Corrugations run in opposite directions in adjoining panels, providing an interesting decorative pattern. Lighted by 66 T12 Slimlines operated at 425 ma and 107 T8 Slimlines operated at 200 ma.

resistant—proof against discoloration from fluorescent lighting.

Because PLEXIGLAS weighs less than half as much as glass, it's easy to install—even in large sections for wall-to-wall luminous ceilings. And because PLEXIGLAS is easily cut, shaped, machined and fabricated, it adapts readily to coffer, cove or trough lighting, completely enclosed units, wall or overhead lighting of all kinds. For full details of PLEXIGLAS Quality Lighting in banks, stores, drafting rooms and classrooms, send for free literature today. There's no obligation.

WRITE FOR THIS FREE LITERATURE TODAY...
and ask any questions you wish about PLEXIGLAS acrylic plastic for lighting.

PLEXIGLAS is a trade-mark, Reg. U.S. Pat. Off. and in principal foreign countries.

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Canadian Distributor: Crystal Glass & Plastics, Ltd., 282 St. Helens Avenue, Toronto, Ont.

NOW

WESTINGHOUSE 90 WATT FLUORESCENT LAMP PRODUCES 54 LUMENS PER WATT

Leading the Field
Since the war, Westinghouse has scored 35 firsts in producing new and improved light sources

New Krypton-Argon Lamps Cut Fluorescent Cost

This new Westinghouse lamp, containing equal amounts of krypton and argon gases, produces 4960 lumens . . . six percent more light than the 85-watt lamp which it supersedes . . . at a total electrical increase of only three watts.

The size of the lamp remains the same . . . 5 feet long and 2½ inches diameter . . . and operates in either 85-watt or the old 100-watt lighting equipment. The 90-watt lamp is 17 percent more efficient than the 100-watt, all-argon lamp which the 85-watt lamp had replaced . . . and it triples the light output of a 100-watt incandescent bulb.

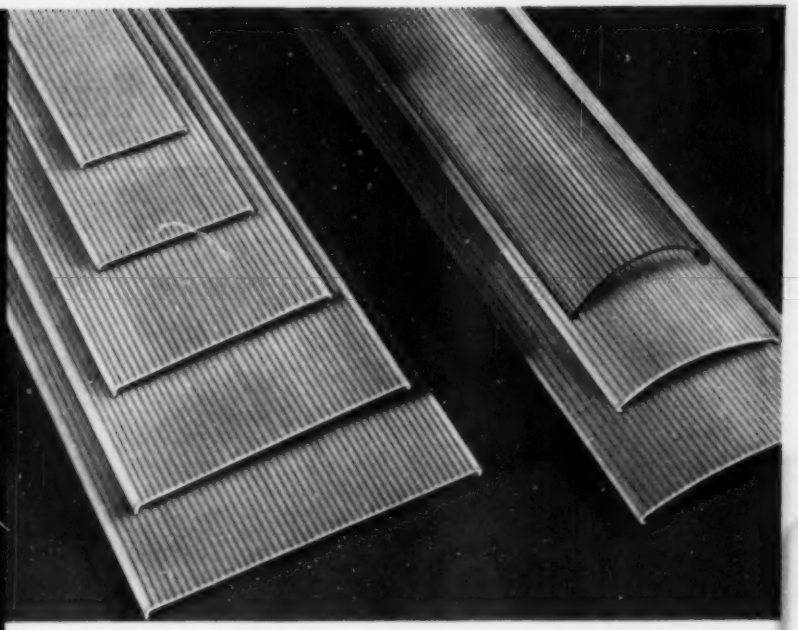
The new 90-watt lamp is available in the five standard shades of white. For more information about this new cost-cutting lamp, call your Westinghouse Lamp Distributor or write to Lamp Division, Westinghouse Electric Corporation, Bloomfield, New Jersey.

YOU CAN BE SURE...IF IT'S

Westinghouse

"POLY-LITE"®

SIDE AND BOTTOM PANELS FOR FLUORESCENT LIGHTING FIXTURES



Save Safely

WITH SANDEE FLUORESCENT PANELS!

1. *SAVE SAFELY*.. WITH UNIFORM FULL THICKNESS!
2. *SAVE SAFELY*.. WITH ELIMINATION OF DANGEROUS OVERHEAD WEIGHT
3. *SAVE SAFELY*.. WITH BREAKAGE REDUCTION OF 80% TO 90%!
4. *SAVE SAFELY*.. WITH LOWER SHIPPING COSTS.. (ABOUT ⅙ THE WEIGHT OF GLASS)
5. *SAVE SAFELY*.. WITH QUALITY THAT GIVES LONG TERM SATISFACTION

added features that bring added savings . .

Standard panels, widths — 2" to 6".. No die cost.. Light stabilized.. Clear or translucent white.. Flat or convex uniform radius. Get bigger value. Ask for samples and prices today!

Sandee MANUFACTURING COMPANY

5050 FOSTER AVENUE CHICAGO 30 ILLINOIS

WORLD'S LARGEST CUSTOM EXTRUDERS OF PLASTICS FOR ALL INDUSTRIES

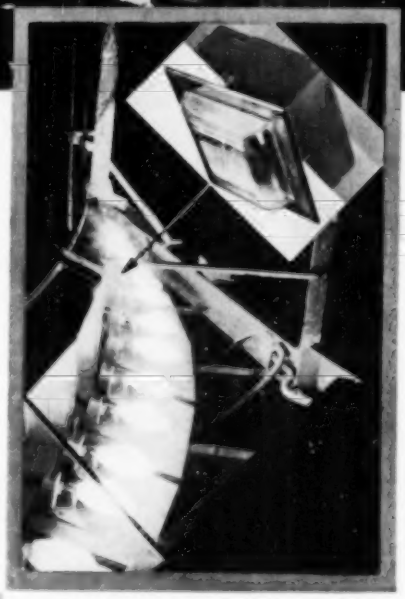
HOLOPHANE Lights Both Houses of Congress

HOLOPHANE Lighting in the newly modernized Chamber of the United States Senate.

DAVID LYNN, *Architect of the Capitol*
FRANCIS P. SULLIVAN, *Associate Architect*
THOMAS W. MARSHALL & JAMES M. GONGWER, *Consulting Engineers*
HARBESON, HOUGH, LIVINGSTON & LARSON, *Consultants*
LEO H. CLEARY, *Electrical Engineer*

In the reconstruction and remodeling of both Houses of Congress, HOLOPHANE units were selected. The specialized knowledge and long-time experience of HOLOPHANE engineers were called upon once again to integrate the lighting with the needs of an important interior.

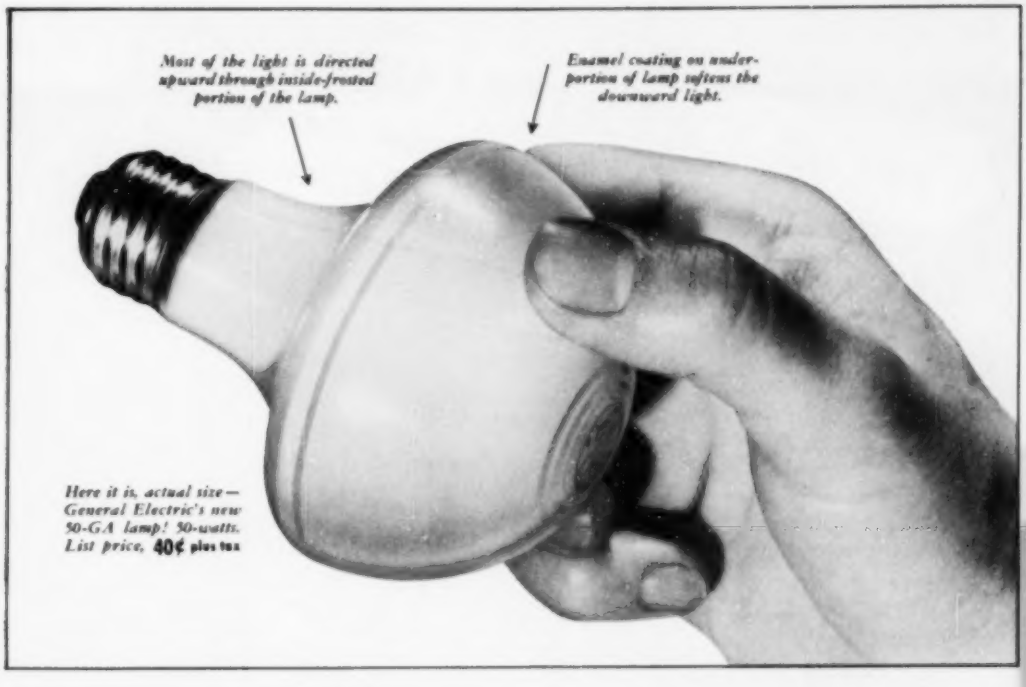
HOLOPHANE Engineering Service, for which there is no charge, stands ready to help you with your needs.



CONTROLENS* installation around cove—units open for relamping.

*Reg. U. S. Pat. Off.

HOLOPHANE COMPANY, Inc.
Lighting Authorities Since 1898 • 342 MADISON AVENUE, NEW YORK 17, N.Y.
THE HOLOPHANE COMPANY, LTD., THE QUEENSWAY, TORONTO 14, ONTARIO


Most of the light is directed upward through inside-frosted portion of the lamp.
Enamel coating on under-portion of lamp softens the downward light.
Here it is, actual size—General Electric's new 50-GA lamp! 50-watts. List price, 40¢ plus tax

General Electric announces a new kind of lamp!

...for everyone who has fixtures like these

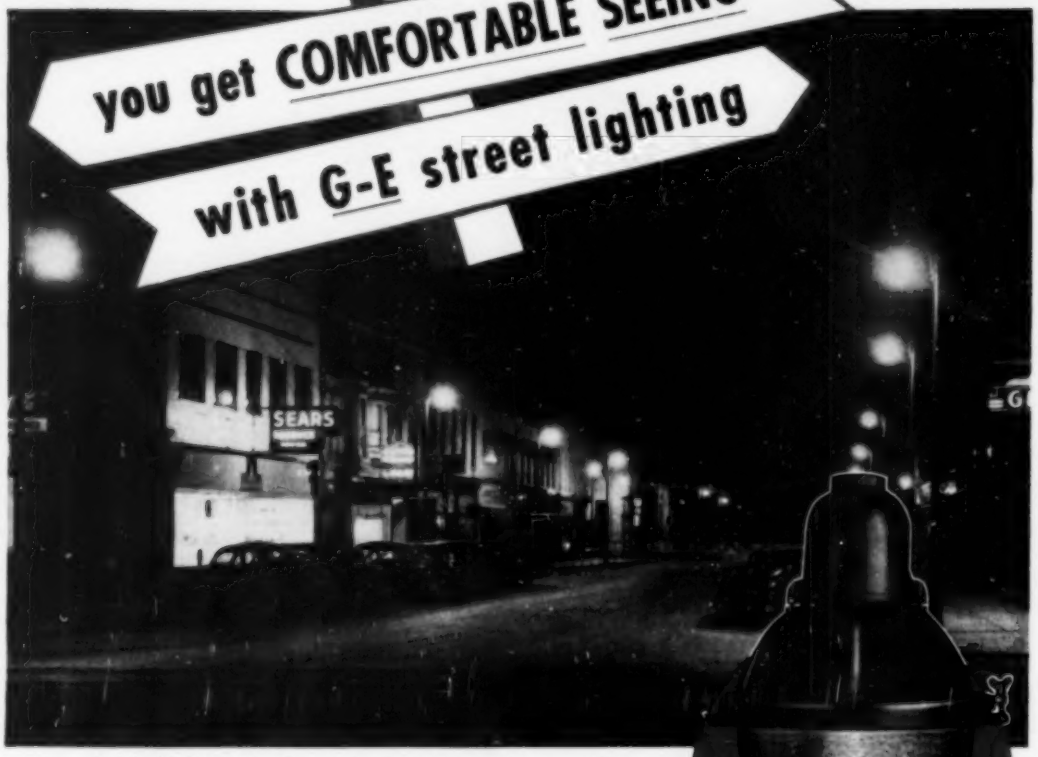
HERE'S a new General Electric lamp bulb to meet the needs of people everywhere who have ceiling fixtures like those shown here. Specifically designed for overhead lighting fixtures where bare lamps in base-up position are now used, this new lamp adds beauty to chandeliers and fixtures, gives a charming, indirect-lighting effect, softens the light to flatter home furnishings and complexions.

The secret lies in a revolutionary new shape which directs much of the light upward, plus an enamel coating on the lower part of the lamp which gives the downward light added glamour and warmth.

Designated the 50-GA lamp, it is now available in 50-watt size, at 40¢, plus tax. It's another example of the General Electric research that works constantly to make G-E lamps STAY BRIGHTER LONGER.

GENERAL ELECTRIC

you get COMFORTABLE SEEING* with G-E street lighting



*Comfortable Seeing—the light you need, exactly where you need it, economically

Here's Seymour, Indiana, another town that has switched from dangerous darkness to leadership in light. City officials realized the inadequacy of their 20 year old lighting system, and that proper lighting would be a business attraction. With the help of their local utility, Seymour decided on a General Electric Comfortable Seeing installation for their business and residential areas.

Now the business streets are flooded with soft, eye-easing light—brightening the store fronts for shoppers—uniformly illuminating the street for the safety of both pedestrians and drivers.

The light on Seymour's residential streets is being more than doubled as old-style radial-wave reflectors are replaced by modern Suburban Reflectors. Photo-electric cells in the modern control circuit automatically turn lights on when they are needed.

TRADE FOLLOWS THE LIGHT

Business streets should be lighted in a manner which favorably influences and attracts night-time shoppers. Lighting and background are often just as important in motivating sales as the merchandise itself. This has long been recognized in connection with show windows and store interiors, but only in recent years are the psychological possibilities of exterior illumination being realized.

Plan on Comfortable Seeing when relighting your town. General Electric has the luminaire which will exactly meet the needs of your business districts, and residential areas. The lighting specialist in the nearest G-E Apparatus Department Sales Office can give you all the details. *Apparatus Department, General Electric Company, Schenectady 5, N. Y.*

This is the Form 79AS an effective luminaire for main street lighting

It's a large-size ornamental unit with a circular light distribution (I.E.S. Type V). Has an Alzak† processed aluminum reflector, light-diffusing rippled globe, die-cast aluminum casing and hinged globe holder. Burns 4000 to 15,000-lumen series lamps, 300- to 860-watt multiple lamps.

†Manufactured under patents of the Aluminum Corporation of America.

GENERAL ELECTRIC

Crowell-Collier Building, New York, N.Y.
Architect: Leonard Schultze Associates, New York, N.Y.
Fixture Manufacturer: Miller Company, Meriden, Conn.
Electrical Contractor: L. K. Comstock, New York, N.Y.
Glass: CORNING ALBA-LITE in 2,600 Reflector Sections

Corning ALBA-LITE for Crowell-Collier Building!

Affords efficient control of fluorescent lighting, accentuates color quality

High efficiency in lighting glassware is always important. It can mean fewer fixtures, better foot-candle values, a more harmonious environment in which to work. It was for these reasons that Corning ALBA-LITE was specified for the Crowell-Collier Building.

ALBA-LITE diffusely transmits 60 to 65% of the light and diffusely reflects 25 to 35%, making its efficiency greater than 90%. Yet its diffusing qualities assure maximum obscurity of light source and minimum panel brightness. In the new Crowell-Collier Building offices illustrated above, 45-50 foot candles of illumination are maintained. The even light transmission and negligible color distortion contribute to harmonious decoration.

High efficiency is only one advantage of ALBA-LITE. It can be bent as required, affording unlimited design flexibility. Widths vary from 2" to 24", lengths from 8" to 100". ALBA-LITE will not warp, discolor, scratch or attract dust. The smooth surface of ALBA-LITE makes cleaning easy.

Bulletin LS-17 gives you complete details on Corning ALBA-LITE and illustrates many ways it is being used. It is yours for the asking. Sign and return coupon below today for your copy.

CORNING GLASS WORKS
CORNING, NEW YORK
Corning means research in Glass

FOR EFFICIENT, ATTRACTIVE LIGHTING . . .
CORNING ALBA-LITE for diffusion of fluorescent light . . . CORNING FOTA-LITE for high level illumination . . . CORNING brand LENS PANELS and PYREX brand LENSLITES for prismatic light control

CORNING GLASS WORKS
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Please send me a free copy of your bulletin LS-17 describing CORNING ALBA-LITE.

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Firm _____
Address _____
City _____ Zone _____ State _____

PHOTOVOLT
UNIVERSAL PHOTOMETER
Mod. 200

A photoelectric foot-candle meter of high sensitivity for accurate measurement of all types of illumination.

- 4 measuring ranges: 0-5, 0-25, 0-100, 0-500 ft.-cdl.
- Simple in operation, dependable, conveniently portable
- Available with cosine-corrected photocell search unit

Also: Mod. 210 with twin-photocell search unit and 0.005 ft.-cdl. / div. for clear registration of lowest light levels in street and highway lighting surveys.

Write for Bull. No. 200 to

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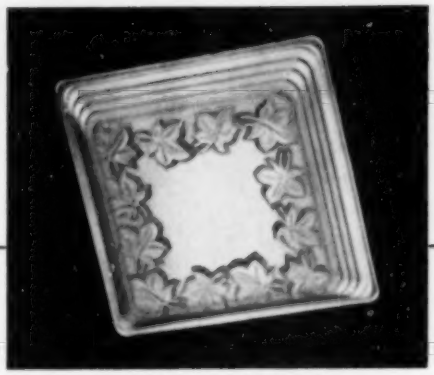
95 Madison Ave. New York 16, N. Y.



No. 1442 8" x 8" x 1¾"

DUNBAR Recessed Lens

For the first time, here are recessed drop lenses which give *added* light. In addition to the general downward illumination, light is directed horizontally to increase the efficiency of this type of fixture.

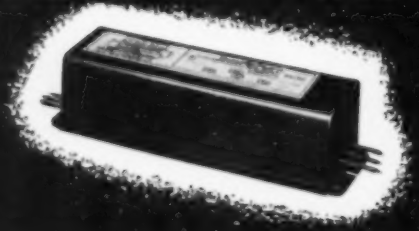
Dunbar's designers, J. O. Reinecke and Associates, have created several new decorative panels for residential as well as commercial installations.

See them at your nearest Dunbar office, or write direct for further information.

Dunbar Glass Corporation

DUNBAR, WEST VIRGINIA
NEW YORK CHICAGO CLEVELAND LOS ANGELES

PERFORMANCE THAT ASSURES
BETTER LIGHT



Acme Electric ballasts have been engineered to eliminate "strobe" effect, provide more lumen output, longer lamp life, quiet operation. Their better performance assure your customer's satisfaction.

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296 WATER STREET CUBA, N. Y.

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Up to the minute in Lighting Practice?

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Day Brite Lighting, Inc., 5411 Bulwer Ave., St. Louis 7, Mo., who make a complete line of commercial and industrial fluorescent lighting fixtures, is expanding their export sales organization. They have an attractive proposition to offer members of the IES in foreign countries and invite correspondence with interested parties.

STREET LIGHTING DESIGNER WANTED

Established manufacturer of outdoor lighting equipment has opening for a top flight lighting engineer who combines administrative ability with design and development experience in street lighting. This position is permanent with unusual promotional possibilities. Starting salary $5,000 to $6,000 a year. Only engineers whose ability has been proven by experience will be considered.

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FLUORESCENT STARTERS

PROTECT

YOUR LAMP LIFE
YOUR BALLASTS
YOU FROM COSTLY MAINTENANCE

THROUGH

Uninterrupted filament preheating providing consistent one-cycle starting.

Automatic cut-out of defective or deactivated lamp.

Automatic reset after cut-out conditions corrected.

See your supplier or write us

INDUSTRIAL STARTER CORP.
6 Pell St., New York 13, N. Y.

why use two men to carry one 8-ft. lamp . . . when one man can carry eight 4-ft. lamps?

Guth 4-ft. SLIMLINE

has all the advantages of the 8-ft. lamp— but scaled down to human, handy size

Easier Service and Maintenance

ONE MAN . . . can carry it, relamp it mount it, maneuver it

- No starters — no starter trouble
- Virtually same lumen output per foot as 8-ft. lamps
- Easier to store
- Safer—safety codes in large national organizations require 2 men to handle anything longer than a man's height

Available in every 2 or 4 — 40W fluorescent fixture in the complete GUTH line. For full details, call your nearest GUTH Resident Engineer or write today for Bulletin 871-I

Guth LIGHTING

THE EDWIN F. GUTH COMPANY / ST. LOUIS 3, MISSOURI

Leaders in Lighting since 1902

391

For Lenses and Filters as YOU Want them . . .

KOPP GLASS

The engineering and manufacturing skill of the Kopp Glass organization guarantees lenses and filters as YOU want them. Colors are faithfully produced and accurately duplicated. Beam control designs give the results you desire, whether you want the light diffused, concentrated, spread or a combination of these. Kopp Glass lenses are dimensionally accurate and uniform.

Write for the 24-page bulletin which describes Kopp products and services.

KOPP GLASS, INC.

KOPP GLASS

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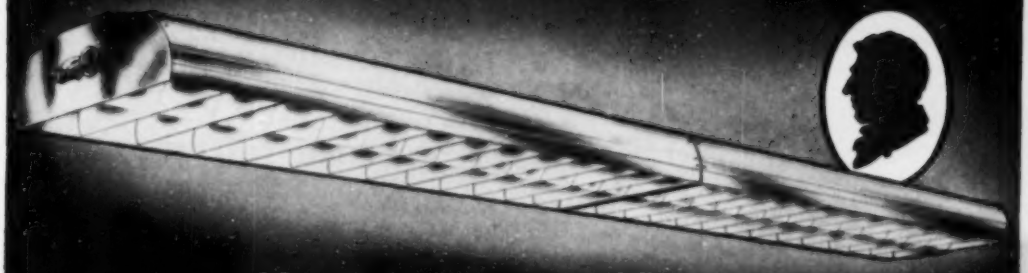
new highs in EFFICIENT & ECONOMICAL LIGHTING FOR SCHOOLS AND OFFICES



THE "Monroe" * in 4 and 8-Foot MODULES FLUORESCENT LUMINAIRES

— Check these Advantages —

- **ECONOMICAL INITIAL COST**
  Simplified design and construction of the basic chassis, side-panels and reflecta-louver assembly result in production economies which are passed on to the ultimate users.

- **LOW INSTALLATION COST**
  One man, working from the side and not from the bottom, hangs the bare chassis in a minimum of time. Side-panel and reflecta-louver assembly snap into position *after* the chassis is hung; no tools required. The 8-foot chassis requires less hangers and less installation time.

- **MAXIMUM EFFICIENCY**
  Permaflector Lighting Engineers have designed the Monroe to give efficiencies up to 83% with 25-35 shielding. Brightness comes well within the I.E.S. recommendations.

- **SIMPLIFIED MAINTENANCE**
  Cleaning or relamping is fast and simple. Reflecta-louver assembly hinges down from either side; full-length fibre-plate snaps out quickly for easy access to wiring channel and ballast.

- **FLEXIBLE APPLICATION**
  Plastic, aluminum or steel side-panels . . . reflector-closures that attach for totally direct lighting . . . and individual or inline installation with or without hangers—make the Monroe the "ideal" unit for many varied applications.

THESE ADVANTAGES ADD UP TO
ALL AROUND LIGHTING ECONOMY!

Write today for complete details on this exceptional series of fluorescent luminaires.

Pittsburgh Permaflector

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Permaflector Lighting Engineers in All Principal Cities
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Please send me your bulletin which describes the Monroe Series in detail and shows specification, photometric and installation details.

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Johnston, R. A., General Electric Co., Minneapolis, Minn.
McGlintock, R. C., Westinghouse Electric Corp., Minneapolis, Minn.
Rogers, A. H., General Electric Co., Minneapolis, Minn.

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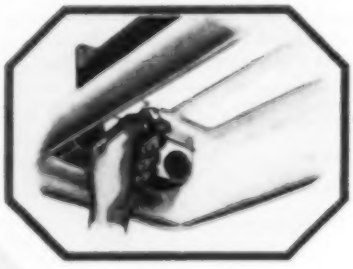

RLM CERTIFICATE: Means compliance with specifications under approved inspection procedure of RLM Standards Institute, Certified by Electrical Testing Laboratories, Inc.

DESIGNED FOR CONTINUOUS RUN MOUNTING: Channel approved for continuous wireway

CAMLOC FASTENERS: Twist 180° to release reflector. Fasteners are aircraft-type, shake-proof, vibration-proof.

SUNBEAM visionaire LIGHTING COMPANY

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- GENERAL TECHNICAL SESSIONS—Three packed sessions including papers on lighting offices, schools, churches, department stores, and in agriculture. Also many studies of the fundamental tasks of seeing and seeing measurements.
- LIGHT SOURCES—Interesting papers on fluorescent, tungsten filament, and mercury sources and their applications.
- STREET LIGHTING—Discussion papers on lighting hazardous areas, tunnels, discomfort glare and other vitally new studies.
- RESIDENCE LIGHTING—Fluorescent lighting, new fixtures and home task studies.
- AVIATION LIGHTING—Airport approach and aircraft lighting; a really fine one.

LADIES' PROGRAM

- TRIP TO STONE CANYON—Luncheon served electronically midst tropical splendor.
- TOUR OF PASADENA—Fabulous Bullock's in Pasadena, famous homes, Pasadena Playhouse, Huntington Library and Art Gallery (home of Gainsborough's "Blue Boy," etc.).
- INTERESTING POINTS IN LOS ANGELES—Olvera St. (Mexican shops), Hollywood Bowl, Lunch at "The" Farmers' Market, Tea at Olive Hill (Frank Lloyd Wright design).

OF INTEREST TO ALL

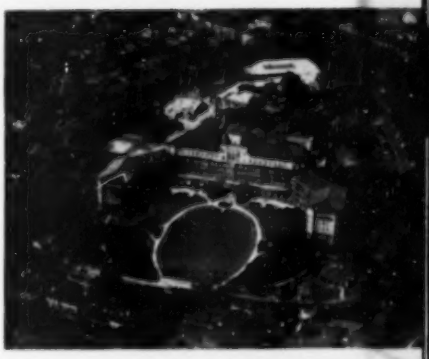
- FIESTA NIGHT—Join in this fun in the spirit of Old California.
- PRESIDENT'S NIGHT—Traditional banquet and ball, famous names, beautiful ladies.
- PROGRESS REPORT—The latest in lamps and lighting from coast to coast shown in the traditional showmanship style of this committee.

LIGHTING SERVICE FORUM—Monday evening, August 21. A new and novel idea by Chairman John Walsh, Pacific Gas & Electric Co., and his committee. Come prepared to be entertained and shown the workings of Planned Lighting.

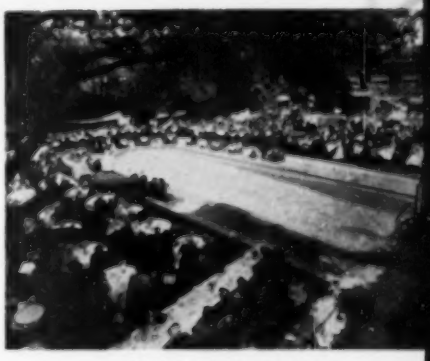
IMPORTANT—For any information about conference write I.E.S. Local Publicity Committee, Room 631, 601 West 5th St., Los Angeles 13, Calif. We will be glad to supply your boss with sound business reasons why he should approve your expense account. Take home new ideas on lighting buildings, department stores, super markets, super service stations, and many other jobs in the manner of the West—a real educational trip.

San Francisco's Golden Gate

Pasadena Playhouse



Air View Hotel Huntington



Hotel Huntington Pool

Smart cure for dull business

Brundage Drug Store, Muskegon, Michigan, before and after installation of modern "Flexi-Module" Lighting System

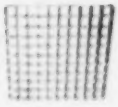
SYLVANIA "Flexi-Module" CEILING

EASY TO INSTALL

1. Utilitarian type Sylvania Fluorescent Fixtures are first mounted on original ceiling. Can be wired for individual control.

2. Adjustable hanger straps and "Star" fasteners secure adjoining grid sections, but permit easy removal of any one. All levelling quickly done from below . . . without any tools.

3. Non-static, aluminum grids keep their good looks, need no dusting or painting. Easy to handle . . . easy to install.



Seems incredible, but it's true . . . the above two photos were taken in the same store . . . before and after the installation of a Sylvania "Flexi-Module" ceiling lighting system.

Amazing transformations like this are being brought about in scores of shops, stores, and offices by Sylvania "Flexi-Module." This ceiling consists of 32-inch aluminum square module grids, joined together and suspended from the original ceiling by adjustable hanger straps.

Between the grids and the original ceiling, Sylvania Fluorescent Lamps pour down their clean, glareless light on all working and sales areas.

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